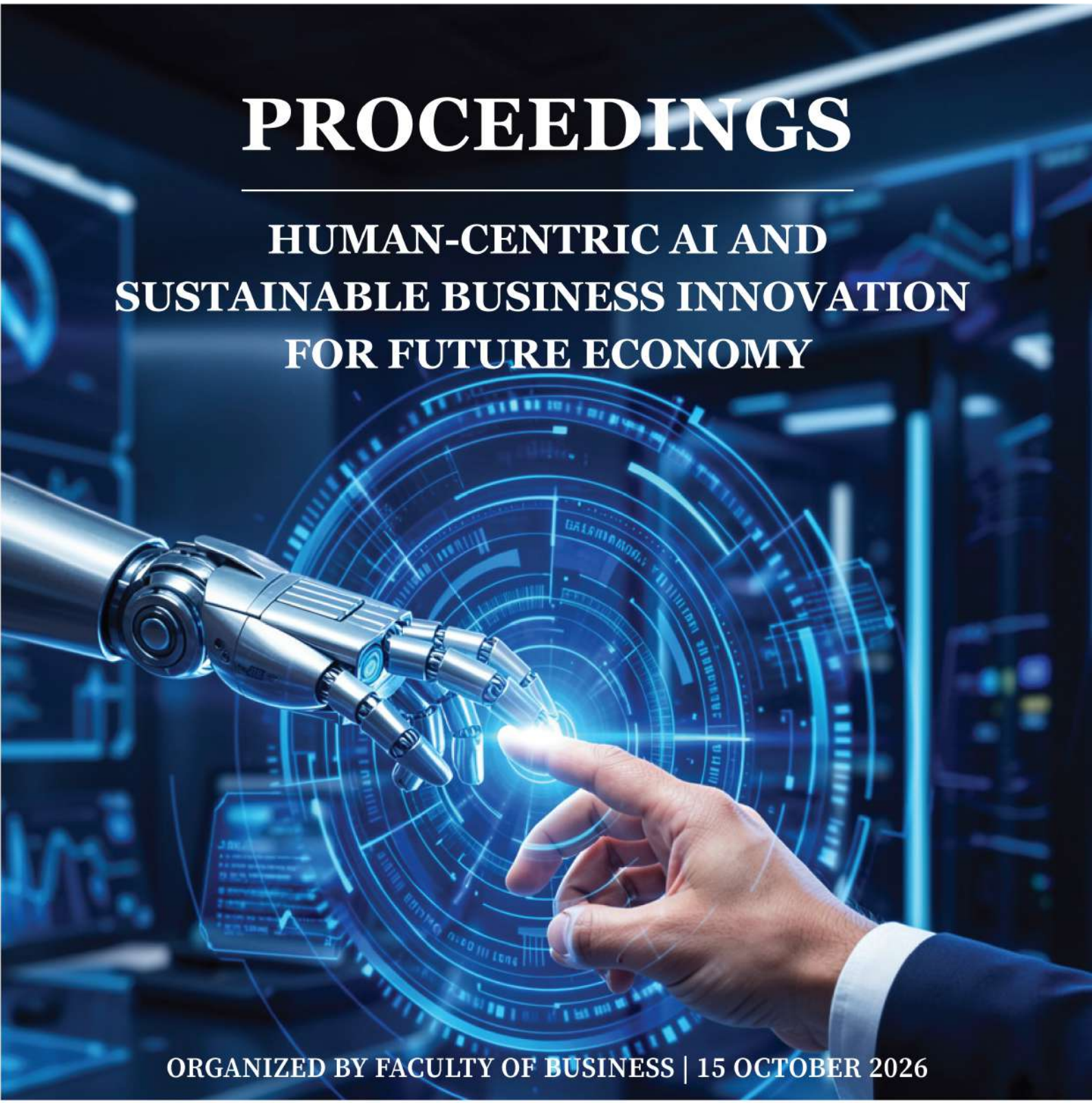
ICOBI 2026

INTERNATIONAL CONFERENCE ON BUSINESS INNOVATION

NSBM GREEN UNIVERSITY TOWN

PROCEEDINGS

HUMAN-CENTRIC AI AND SUSTAINABLE BUSINESS INNOVATION FOR FUTURE ECONOMY



ORGANIZED BY FACULTY OF BUSINESS | 15 OCTOBER 2026

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PREFACE

On behalf of the organizing committee of the International Conference on Business Innovation (ICOBI) 2026, it is our great pleasure to welcome all the authors and delegates of this esteemed event hosted by the Faculty of Business of NSBM Green University, Sri Lanka. We trust that the contents within will prove to be not only insightful but also transformative. For the ninth consecutive year, NSBM Green University proudly hosts the International Conference on Business Innovation (ICOBI), pushing the boundaries of academic discourse. This conference is a testament to the continuous commitment towards addressing the pressing global challenges through research and innovation while exploring the intersection of business and technology.

This year, under the theme "Human-Centric AI and Sustainable Business Innovation for Future Economy," the conference provides a dynamic platform for academics, researchers, and professionals to present and exchange their ideas, and discuss cutting-edge research that spans a wide range of disciplines to reshape communities and industries. Over the course of the event, we aim to foster dialogue and explore innovative solutions on a variety of themes that drive progress in the modern world. ICOBI 2026 serves as a vital platform to bring together local and international researchers, academics, and industry experts to discuss the profound impact of redefining business in the global innovative landscape.

The papers included in these proceedings underwent a rigorous double blind review process, ensuring that the contribution reflects the highest standards of scholarship and innovation.

We are also pleased to highlight that the highest-scoring papers will be published in a special issue by Taylor & Francis, further amplifying the impact of research presented at the conference. These efforts demonstrate the conference's commitment to academic integrity.

We extend our heartfelt gratitude to our keynote speakers, panelists, and participants whose insights and experiences have greatly enriched our discussions. We also wish to acknowledge the tireless efforts of the organizing committee, the reviewers and the volunteers who made this conference a success. We are confident that the research shared here will inspire new ideas and collaborations that will pave the way for more sustainable and innovative future in business.

We wish all participants a stimulating and rewarding conference experience.

The Conference Organizing Committee
ICOBI 2026

Message from the Vice-Chancellor



It is my great pleasure to extend my warmest greetings for the success of the 9th International Conference on Business Innovation (ICOBI 2026), hosted by the Faculty of Business, NSBM Green University. I am delighted to welcome our distinguished keynote dignitaries, scholars, practitioners, policymakers, and research delegates to this significant academic gathering.

As a university firmly rooted in progressive education and holistic student development, NSBM Green University remains dedicated to fostering a vibrant culture of research excellence and global academic engagement. In an era where computational power and machine intelligence redefine industrial paradigms, our chosen theme 'Human-Centric AI and Sustainable Business Innovation for Future Economy' articulates an urgent imperative. We stand at a critical juncture where innovation cannot be measured solely by computational efficiency or commercial yields; it must be consciously steered toward human dignity, environmental resilience, and shared societal prosperity.

ICOBI has evolved into an esteemed international forum, providing a collaborative forum where interdisciplinary scholarship directly informs future economies. I am particularly pleased to observe that this 9th edition reflects unprecedented intellectual vigor, with 116 research papers accepted through rigorous evaluation and 80 outstanding papers shortlisted for inclusion in the prestigious Taylor & Francis Conference Proceedings. This exemplifies our uncompromising commitment to scholarly quality and international peer-reviewed dissemination.

I extend my sincere appreciation to the authors for their insightful inquiries, our distinguished keynote speakers for providing visionary compass, the international reviewers for their academic rigor, and the conference organizing committee for their tireless stewardship. May the deliberations of ICOBI 2026 generate enduring partnerships and actionable knowledge to shape a resilient, humane, and sustainable global economy.

Thank you.
Prof. E. A. Weerasinghe
Vice Chancellor
NSBM Green University

Message from the Senior Deputy Vice-Chancellor



It is a privilege to extend my best wishes and a heartfelt welcome to all joining us for the 9th International Conference on Business Innovation (ICOBI 2026) at NSBM Green University.

The role of contemporary higher education extends beyond the dissemination of knowledge; it is equally about fostering resilient knowledge ecosystems that connect academic inquiry with meaningful industrial transformation. As organisations navigate increasingly complex and interconnected challenges, cross-disciplinary collaboration has become an essential driver of innovation, progress, and sustainable development.

The theme of ICOBI 2026, "Human-Centric AI and Sustainable Business Innovation for Future Economy," invites us to consider how artificial intelligence, data analytics, management disciplines, and sustainability can be integrated to create a future where technology enhances human potential and drives responsible innovation. Through its diverse research contributions, the conference provides a valuable platform for advancing scholarly dialogue, encouraging interdisciplinary perspectives, and exploring innovative approaches to the evolving challenges of business and society.

I convey my warmest gratitude to the contributing authors, insightful keynote speakers, peer reviewers, and the organizing team whose dedication has made this conference a benchmark of intellectual vitality. I am confident that the dialogues initiated across these proceedings will stimulate groundbreaking research partnerships and industry solutions. I wish all participants an intellectually rewarding and impactful conference.

Thank you.
Prof. Chaminda Rathnayake
Senior Deputy Vice Chancellor
NSBM Green University

Message from the Head of Academic Development and Quality Assurance



I am delighted to convey my warm greetings to the 9th International Conference on Business Innovation (ICOBI 2026), which brings together scholarly perspectives on "Human-Centric AI and Sustainable Business Innovation for Future Economy."

Academic credibility and institutional excellence are built upon a strong foundation of scholarly quality, ethical integrity, and methodological rigour. At NSBM Green University, we remain committed to upholding these principles through robust quality assurance practices that strengthen credibility of our academic and research endeavours.

As artificial intelligence and automation continue to reshape research and practice, the importance of sound quality assurance frameworks and ethical standards has become increasingly significant. The theme of ICOBI 2026 calls for research that goes beyond technological advancement to embrace human values, ethical responsibility, sustainability, and the broader impact of innovation on society. The rigorous double-blind peer-review process adopted for ICOBI 2026 also reflects our commitment to maintaining high standards of scholarly integrity and research quality that contributes meaningfully to academic and professional discourse.

I extend my heartfelt appreciation to our authors for upholding high research standards, our peer reviewers for their indispensable critical stewardship, and the organizing committee for ensuring procedural excellence throughout. May ICOBI 2026 continue to set new benchmarks for scholarly quality and inspire ethical, sustainable innovation.

Thank you.
Prof. Baratha Dodankotuwa
Head of Academic Development and Quality Assurance
NSBM Green University

Message from the Deputy Vice-Chancellor – Academic/Conference Chair



It is my distinct honor and profound joy as Conference Chair, to present the proceedings of the 9th International Conference on Business Innovation (ICOBI 2026), hosted by the Faculty of Business, NSBM Green University.

Now entering its ninth consecutive year, ICOBI has matured into a premier international platform for intellectual exchange, pioneering research, and transformative ideas. Over the years, ICOBI has consistently provided an intellectual sanctuary where diverse perspectives merge to solve complex socioeconomic puzzles.

This year's conference marks an extraordinary milestone. Our chosen theme, 'Human-Centric AI and Sustainable Business Innovation for Future Economy', underscores a decisive global calling; to humanize artificial intelligence and deploy business innovation as a driving force for sustainable, inclusive development.

Following a rigorous and competitive double-blind peer-review process, we have accepted 116 high-quality research papers across our eight conference tracks. Furthermore, 80 exceptional manuscripts have been shortlisted for publication in the Taylor & Francis Conference Proceedings.

An undertaking of this magnitude is made possible only through the collective synergy of many devoted individuals. I convey my heartfelt gratitude to the Vice Chancellor and senior management of NSBM Green University for their steadfast leadership and visionary support. I thank our eminent keynote speakers for sharing their thought-provoking insights; our authors for entrusting ICOBI with their groundbreaking research; our diligent peer reviewers and track chairs for maintaining uncompromising academic rigor; and our publishing partners, Taylor & Francis, for their invaluable collaboration. Finally, I salute the organizing committee, faculty members, and student ambassadors whose tireless dedication made this event a reality.

May ICOBI 2026 inspires meaningful dialogues, lasting partnerships, and innovative solutions for the future economy. Welcome to ICOBI 2026!

Thank you.
Prof. Thilini De Silva
Deputy Vice Chancellor – Academic
Conference Chair, ICOBI 2026

Message from Dean, Faculty of Business



On behalf of the Faculty of Business at NSBM Green University, it is my absolute pleasure and honor to present the proceedings of the 9th International Conference on Business Innovation (ICOBI 2026).

The Faculty of Business remains committed to advancing progressive business education and research that responds to the evolving needs of organisations, industries, and society. Over the years, ICOBI has provided a valuable platform for bringing together diverse perspectives and encouraging meaningful dialogue on emerging developments in business and management.

The theme of this year's conference, "Human-Centric AI and Sustainable Business Innovation for Future Economy," reflects the growing need to balance technological advancement with human values, sustainability, and responsible business practice. The interdisciplinary nature of ICOBI 2026 provides an opportunity to explore these dimensions from multiple perspectives, connecting academic research with contemporary challenges faced by businesses and economies.

I extend my sincere appreciation to our distinguished keynote speakers, authors, track chairs, reviewers, and the organising committee for their dedication and valuable contributions in creating a platform for knowledge exchange, scholarly collaboration, and meaningful engagement. I trust that the research and discussions emerging from ICOBI 2026 will inspire new perspectives, strengthen collaborative networks, and contribute to the advancement of business knowledge and practice.

I wish all participants an enriching and rewarding conference experience..

Ms. Anne Pathiranage
Dean, Faculty of Business
ICOBI 2026

KEYNOTE ADDRESS 1



Prof. Jacquline Tham
Associate Professor
Management & Science University
Malaysia

Human-Centric AI Leadership: Driving Sustainable Business Innovation and Future-Ready Organizations in the AI Economy

Abstract

Artificial Intelligence (AI) is transforming the way organisations operate, innovate, and compete in the global economy. However, the success of AI adoption depends not only on technological capabilities but also on the ability of leaders to place people, ethics, and sustainability at the centre of decision-making. In this keynote, Associate Professor Dr. Jacqueline Tham explores how Human-Centric AI Leadership can enable organisations to leverage AI responsibly while fostering innovation, resilience, and sustainable growth. The session will examine the evolving role of leadership in the digital era, highlighting the importance of balancing technological advancement with human values, inclusivity, and social responsibility. Drawing from industry experience, academic research, and real-world examples, the keynote will discuss how businesses and educational institutions can develop future-ready talent, cultivate a culture of continuous learning, and embrace responsible AI practices that create long-term value for stakeholders. Participants will gain practical insights into leading digital transformation, driving sustainable business innovation, and building organizations that thrive in the AI economy while remaining committed to human well-being and societal progress.

Key Message: The future belongs to organizations that use AI not merely as a tool for efficiency, but as a catalyst for empowering people, fostering sustainable innovation, and creating meaningful impact for society.

KEYNOTE ADDRESS 2



Mr. Supun Weerasinghe
Group Chief Executive/ Non-Independent, Executive Director
Dialog Axiata PLC

Human-Centric AI and Sustainable Business Innovation for Future Economy

Abstract

Each major technological transition has done more than accelerate existing practice; it has reconfigured entire industries and the institutions around them. Artificial intelligence and autonomous systems are the latest such shift, and they force a more fundamental question than adoption: what is this capability for? The most defensible answer is a symbiotic partnership between humans and machines, in which each compensates for the limits of the other. Human beings contribute judgment, trust, imagination and moral reasoning. Machines contribute speed, scale and consistency. Value is created at the intersection of the two, and an economy organised around that complementarity is better placed to grow sustainably and to advance human well-being.

Realising this partnership is, first and foremost, a problem of leadership and culture. Strategy, structure and culture must be redesigned together with the technology, rather than layered on top of it. Upskilling is the hardest and most urgent step, since it moves people from executing tasks to orchestrating intelligence. Equally, governance cannot be an afterthought. Clear accountability, meaningful human oversight of consequential decisions, transparency in how systems are used, and vigilance over bias, privacy and security are the guardrails that sustain legitimacy. Ethics must be embedded in design, because trust is the precondition for collaboration between people and machines.

The resulting enterprise assigns routine and data-intensive work to machines, and reserves creativity, relationships and ethically weighty judgment for people. The dividends are faster innovation, richer customer and employee experience, and organisations able to adapt as conditions shift, provided efficiency gains are reinvested in capability and growth rather than cost reduction alone. The decisive competencies are technological fluency, agility, sound judgment, collaboration and character.

The ambition is a future economy in which technology amplifies human potential, and innovation is measured by its lasting value to people, organisations and society.

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Perceived Parental Financial Behaviour, Financial Literacy and Investment Behaviour of Young Adults: Evidence from the Western Province, Sri Lanka

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ABSTRACT: This study examines how financial literacy and perceived parental financial behaviour relate to the investment behaviour of young adults aged 20-29 in the Western Province of Sri Lanka. A cross-sectional survey was conducted using a structured questionnaire, and 187 usable responses were obtained from 400 distributed through convenience sampling in Colombo, Gampaha and Kalutara. Data were analysed using reliability analysis, Pearson correlation and multiple regression. The two predictors jointly explained 66.2% of the variance in investment behaviour. Both were positively and significantly associated with investment behaviour, but perceived parental financial behaviour showed a much stronger standardized association ($\beta = 0.782$, $p < 0.001$) than financial literacy ($\beta = 0.100$, $p = 0.025$). The findings suggest that learning within the family may complement formal financial education. Because the sample was concentrated among finance-related respondents, the findings should not be taken as representative of all young adults in Sri Lanka.

Keywords: financial literacy, perceived parental financial behaviour, investment behaviour, financial socialization, young adults, Sri Lanka

1 INTRODUCTION

Financial decisions have become increasingly important in the lives of young adults. The expansion of financial products, digital financial services and online investment platforms has created more opportunities for individuals to save and invest, but it has also placed greater responsibility on individuals to understand financial choices and manage risk. Decisions made during early adulthood can have lasting consequences because saving and investment outcomes accumulate over time.

Financial literacy is widely recognised as an important component of sound financial decision-making. It refers broadly to the knowledge and skills required to understand financial concepts and make informed financial decisions. Earlier research has shown that financially literate individuals are more likely to plan, participate in investment markets and make informed financial choices [1], [2]. Financial knowledge can also help individuals understand investment risk, returns and diversification [3]. However, financial knowledge alone does not necessarily guarantee appropriate financial behaviour. Individuals may possess financial knowledge but fail to apply it because of limited confidence, behavioural tendencies, social influences or a lack of opportunities to act on that knowledge [4].

Financial behaviour is therefore shaped within a wider social environment. Financial socialization describes the process through which individuals acquire financial knowledge, attitudes and behaviours through interactions with parents, peers, educational institutions and the broader social environment [5]. Among these influences, parents occupy a particularly important position because they are usually the first people through whom children observe everyday

financial practices. Parents may influence young adults through direct conversations about money as well as through their own behaviour, including saving, budgeting, investing and planning for future needs [5], [6]. Social Learning Theory provides a useful explanation for this process. Individuals can learn behaviours by observing the actions of others and by seeing the consequences associated with those actions [7]. From this perspective, young adults may develop financial habits partly by observing how their parents manage money. A young person who repeatedly observes parents saving regularly, comparing financial alternatives or investing for long-term goals may acquire behavioural patterns that later influence his or her own financial decisions.

Recent evidence continues to highlight the importance of parental financial socialization. Chawla, Bhatia and Singh [8] found that perceived parental financial behaviour was significantly related to financial literacy among young adults and that financial literacy was associated with investment behaviour. Similarly, research among young adults in Ghana found that parental financial behaviour was associated with both financial literacy and savings and investment behaviour [9]. Evidence from India also indicates that parental financial socialization can influence financial literacy and financial behaviour [10], [11]. These findings suggest that financial learning does not occur only through formal education; it can also take place through everyday experiences within the family. The relationship between financial literacy and investment behaviour has also received attention in Sri Lanka. Kumari [12], studying undergraduates in the Western Province, reported a positive and significant relationship between financial literacy and investment decisions. More recent evidence from emerging-market settings similarly indicates that financially literate individuals are more likely to make informed investment decisions [13]. These findings make financial literacy particularly relevant when examining the investment behaviour of young adults in Sri Lanka. Despite this evidence, there remains a need to examine financial literacy and parental financial behaviour together when explaining young adults' investment behaviour. Relatively little evidence is available for Sri Lanka on the extent to which the financial behaviour young adults perceive in their parents is associated with their own investment behaviour after accounting for financial literacy. The Western Province provides an important setting for such an investigation because it is the country's main commercial and financial centre and provides comparatively high exposure to universities, employment opportunities, financial institutions and investment services.

Accordingly, this study focuses on two relationships. First, it examines whether financial literacy is significantly associated with the investment behaviour of young adults. Second, it examines whether perceived parental financial behaviour is significantly associated with investment behaviour. The study does not test whether parental financial behaviour causes or predicts financial literacy. Although previous literature suggests that such a relationship may exist [8]-[11], examining that pathway requires a separate hypothesis and an analytical model specifically designed to test it.

The study therefore has two objectives:

1. To examine the relationship between financial literacy and investment behaviour among young adults in the Western Province of Sri Lanka.
2. To examine the relationship between perceived parental financial behaviour and investment behaviour among young adults in the Western Province of Sri Lanka.

The findings may be useful to financial educators, policymakers, financial institutions and families seeking to encourage responsible investment behaviour among young adults.

2 LITERATURE REVIEW

2.1 *Financial literacy and investment behaviour*

Financial literacy provides individuals with the knowledge required to understand financial products, evaluate risk and make informed financial decisions. Lusardi and Mitchell [1] argue that financial literacy is economically important because it affects decisions involving saving, borrowing, retirement planning and investment. Similarly, van Rooij, Lusardi and Alessie [2] found that financially literate households were more likely to participate in the stock market.

The relationship between financial knowledge and financial behaviour, however, is not necessarily automatic. Hilgert, Hogarth and Beverly [14] found an association between financial knowledge and household financial management, while Xiao and O'Neill [15] showed that financial education is associated with several dimensions of financial capability. These findings suggest that knowledge can facilitate desirable behaviour but that other personal and contextual factors also matter. Recent evidence supports the continuing relevance of financial literacy to investment decisions. Shroff et al. [13], examining investors in an emerging-market context, found that higher financial literacy was positively associated with investment decisions. In Sri Lanka, Kumari [12] reported a positive and significant effect of financial literacy on investment decisions among undergraduates in the Western Province.

Based on this literature, the first hypothesis is proposed:

H1: Financial literacy is positively and significantly associated with the investment behaviour of young adults.

2.2 *Financial literacy among young adults*

Young adulthood is an important stage in financial development because individuals increasingly begin to manage income, savings, credit and investment decisions independently. However, young adults often have limited financial experience, which can make them more dependent on information obtained from family members, educational institutions, peers and online sources. Earlier research found differences in financial literacy according to demographic and educational characteristics [16], [17]. Financial capability also depends on whether individuals have the opportunity and confidence to apply their financial knowledge in real-life situations [15].

Recent studies reinforce the importance of financial socialization during this stage. Utkarsh et al. [18], studying young adults in India, found that financial discussions with parents during childhood were positively related to later financial well-being. Goyal, Kumar and Hoffmann [11] also found that financial socialization and psychological characteristics play important roles in the personal financial management behaviour of young professionals in India. These findings suggest that financial literacy should not be viewed in isolation from the social environment in which young adults develop their financial habits.

2.3 *Perceived parental financial behaviour and financial socialization*

Parents are among the earliest and most consistent sources of financial learning. Financial socialization can occur through explicit mechanisms, such as discussions about saving and spending, as well as implicit mechanisms, such as observing parents' everyday financial behaviour [5], [6]. Gudmunson and Danes [5] argue that family financial socialization includes both financial behaviours observed by children and communication about financial matters. Shim et al. [6] similarly found that parents, together with work experience and education, play important roles in shaping the financial attitudes and behaviours of young adults.

More recent research provides further support for this perspective. Chawla, Bhatia and Singh [8] found that perceived parental financial behaviour significantly influenced financial literacy and was also relevant to investment behaviour among young adults. Owusu et al. [9] found that parental financial behaviour was an important predictor of both financial literacy and savings and investment behaviour. In India, Subramanian and Arjun [10] reported that implicit parental financial socialization positively influenced students' financial literacy. Kaur and Singh [19] also found that family financial socialization was related to financial self-efficacy and financial behaviour among university students in India.

These findings indicate that young adults may learn financial behaviour not only from formal financial education but also from observing the financial practices of people close to them.

Therefore, the second hypothesis is proposed:

H2: Perceived parental financial behaviour is positively and significantly associated with the investment behaviour of young adults.

2.4 *Theoretical foundation*

The present study uses two complementary theoretical perspectives to explain the two hypothesised relationships.

2.4.1 *Social Learning Theory*

Social Learning Theory proposes that individuals learn behaviours by observing others, interpreting their actions and reproducing behaviours that appear appropriate or rewarding [7]. Parents are particularly important models because young people are exposed to their financial practices repeatedly during childhood and adolescence. Accordingly, observing parental saving, investment, budgeting and long-term financial planning may provide young adults with behavioural models that influence their own investment behaviour. Social Learning Theory therefore provides the theoretical basis for H2: perceived parental financial behaviour - investment behaviour.

2.4.2 *Theory of Planned Behavior*

The Theory of Planned Behavior (TPB) proposes that behaviour is influenced by behavioural intentions, which are shaped by attitudes, subjective norms and perceived behavioural control [20]. Financial literacy can contribute to these processes by improving an individual's understanding of financial products, risks and possible outcomes. Greater knowledge may make individuals feel more capable of evaluating investment opportunities and acting on their financial intentions. Thus, TPB provides a complementary explanation for why financial literacy may be associated with investment behaviour. It supports H1: financial literacy - investment behaviour. Importantly, the present study does not claim that financial literacy is a mediator between parental financial behaviour and investment behaviour. Although previous studies suggest that parental behaviour may also contribute to financial literacy [8]-[10], that pathway is outside the empirical model tested in this study.

2.5 *Conceptual framework*

The conceptual framework contains two parallel explanatory variables: financial literacy (FL) and perceived parental financial behaviour (PFB). Both are hypothesised to be positively associated with investment behaviour (IB), as shown in Figure 1.

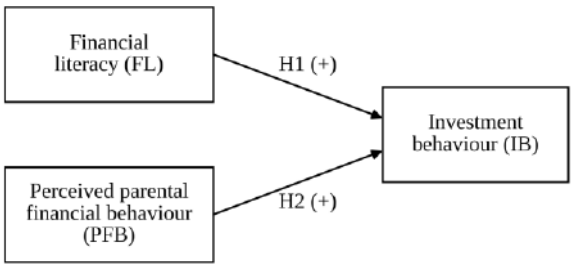


Figure 1. Conceptual framework of the study

The framework deliberately does not include a PFB - FL arrow because that relationship is not tested in the present study.

3 METHODOLOGY

3.1 *Research design*

The study adopted a quantitative, positivist and deductive research approach. A cross-sectional survey design was used to collect data from young adults aged 20-29 living in the Western Province of Sri Lanka.

The cross-sectional design was appropriate because the purpose was to examine the relationships among financial literacy, perceived parental financial behaviour and investment behaviour at a particular point in time. However, because the variables were measured simultaneously, the results should be interpreted as associations rather than evidence of causal relationships.

3.2 *Population and study area*

The target population consisted of young adults aged 20-29 residing in the Western Province of Sri Lanka, covering Colombo, Gampaha and Kalutara districts.

The Western Province was selected for two main reasons. First, it is the country's main commercial and financial centre and contains a high concentration of financial institutions, employment opportunities, universities and other educational institutions. Second, the province provides young adults with relatively greater exposure to formal financial services and investment opportunities.

At the same time, focusing on the Western Province limits the geographical generalisability of the findings. Young adults living in rural areas and regions with lower access to formal financial services may have different financial experiences and investment opportunities. This limitation is considered explicitly in Section 6.

3.3 *Sampling and data collection*

The study used a non-probability convenience sampling approach. A total of 400 questionnaires were distributed to young adults through universities, workplaces and other institutions located across Colombo, Gampaha and Kalutara districts. Both online and physical distribution methods were used.

Participation was voluntary and anonymous. Respondents were included if they were between 20 and 29 years of age and lived in the Western Province. Of the 400 questionnaires distributed, 187 usable responses were obtained, representing a response rate of approximately 46.8%.

The original target of approximately 384 respondents was based on the sample-size recommendation of Krejcie and Morgan [21] for large populations. The final sample of 187 is therefore smaller than that benchmark. Consequently, the findings are interpreted as evidence from the surveyed respondents rather than as statistically representative estimates for all young adults in the Western Province.

Because respondents were recruited through accessible institutions and voluntary participation, the sampling procedure should not be described as stratified random sampling. Although efforts were made to obtain respondents from all three districts, the study does not claim that every young adult in the population had a known or equal probability of selection.

3.4 *Measurement of variables*

Data were collected using a structured, self-administered questionnaire. Financial literacy was measured using 10 objective knowledge items. Each item was coded according to whether the respondent provided the correct answer, and the overall financial literacy score was calculated as the proportion of correct answers. Therefore, the financial literacy variable ranges from 0 to 1, where higher values represent greater objective financial knowledge.

Perceived parental financial behaviour was measured using five statements relating to respondents' perceptions of their parents' financial practices. Responses were recorded on a five-point Likert scale ranging from 1 = strongly disagree to 5 = strongly agree. Higher scores indicate more positive perceived parental financial behaviour. Investment behaviour was measured using five five-point Likert-scale items, with higher scores indicating more active or desirable investment behaviour.

The financial literacy score and the two Likert-scale constructs were deliberately retained on their original measurement scales. Consequently, their raw means should not be compared directly. The financial literacy mean is interpreted as a proportion correct, whereas the PFB and IB means are interpreted using the five-point Likert scale.

3.5 *Data analysis*

The data were analysed using IBM SPSS. Descriptive statistics were used to summarise respondent characteristics and the main study variables.

Cronbach's alpha was used to assess the internal consistency of the multi-item scales. Pearson correlation analysis was used to examine the bivariate relationships among financial literacy, perceived parental financial behaviour and investment behaviour. The results are reported in Table 2. Multiple linear regression was then employed to examine the combined relationship of financial literacy and perceived parental financial behaviour with investment behaviour.

The regression model was specified as follows (Equation 1):

$$IB = \beta_0 + \beta_1 FL + \beta_2 PFB + \varepsilon \quad (1)$$

where IB = investment behaviour; FL = financial literacy; PFB = perceived parental financial behaviour; β_0 = constant; β_1 and β_2 = regression coefficients; and ε = error term.

Statistical significance was evaluated at the 5% significance level.

4 DATA ANALYSIS AND FINDINGS

4.1 *Sample profile*

All 187 usable questionnaires were complete because the online questionnaire was designed with required responses for all items. The responses were coded and analysed using SPSS. Table 1 summarises the sample profile.

The sample was dominated by respondents aged 25-29, who accounted for 85.0% of the observations. Male respondents represented 58.3% and female respondents 41.7%.

The most important characteristic of the sample is its educational composition. Approximately 84.5% of respondents had a Commerce background and 84.5% reported Finance as their major. This concentration is important when interpreting the findings because finance-trained respondents are likely to have greater exposure to financial concepts and investment-related information than young adults from non-finance backgrounds.

This composition may partly explain the high financial literacy scores observed in the study. It also means that the findings should not be interpreted as representative of the broader population of young adults.

Table 1. Demographic characteristics of respondents (n = 187)

Variable	Category	Frequency	Percentage (%)
Age	20-24 years	28	15.0
	25-29 years	159	85.0
Gender	Male	109	58.3
	Female	78	41.7
Parental income	Below Rs. 500,000	39	20.9
	Rs. 500,000-1 million	91	48.7
	Rs. 1-2 million	42	22.5
	Rs. 2-3 million	10	5.3
	Above Rs. 3 million	5	2.7
Academic stream	Science	21	11.2
	Commerce	158	84.5
	Arts	3	1.6
	Technology	5	2.7
Work experience	No experience	16	8.6
	1-3 years	155	82.9
	More than 3 years	16	8.6
Major	Finance	158	84.5
	Non-finance	29	15.5

Source: Survey data.

4.2 *Reliability analysis*

Table 2. Reliability analysis

Construct	Items	Cronbach's Alpha
Financial literacy	10	0.886
Perceived parental financial behaviour	5	0.909
Investment behaviour	5	0.827

Source: SPSS output.

Cronbach's alpha was used to assess the internal consistency of the multi-item constructs. A value of approximately 0.70 or above is commonly considered acceptable for research purposes [22]. The results are reported in Table 2.

All reported reliability coefficients exceed 0.70. The results therefore indicate satisfactory internal consistency for the multi-item measures used in the study.

4.3 *KMO and Bartlett's test*

Sampling adequacy and the suitability of the item correlation structure were assessed using the Kaiser-Meyer-Olkin measure and Bartlett's test of sphericity [23]. The results are shown in Table 3.

Table 3. KMO and Bartlett's test

Construct	KMO	Bartlett's Test Sig.
Financial literacy	0.877	<0.001
Perceived parental financial behaviour	0.849	<0.001
Investment behaviour	0.764	<0.001

Source: SPSS output.

The KMO values exceeded 0.60 for all three constructs, while Bartlett's test was statistically significant at $p < 0.001$. These results indicate adequate inter-item correlation for the exploratory assessment of the measurement structure.

4.4 *Descriptive statistics*

Table 4 presents the descriptive statistics of the study variables. The financial literacy mean of 0.930 indicates that respondents answered approximately 93% of the financial knowledge questions correctly. The relatively small standard deviation (0.068) indicates limited variation in financial literacy.

This high score should be interpreted in the context of the sample. Since 84.5% of respondents had a Finance major, the high level of financial literacy is not surprising. It also suggests a possible ceiling effect, whereby limited variation in financial literacy may make it more difficult to detect its association with investment behaviour.

The PFB mean of 4.290 indicates that respondents generally perceived their parents' financial behaviour positively. The IB mean of 4.200 similarly indicates relatively high reported investment behaviour.

Table 4. Descriptive statistics

Construct	Measurement scale	Mean	SD
Financial literacy	Proportion correct (0-1)	0.930	0.068
Perceived parental financial behaviour	Five-point Likert scale	4.290	0.731
Investment behaviour	Five-point Likert scale	4.200	0.640

Source: SPSS output.

Importantly, these means should not be compared numerically across constructs, because financial literacy is measured as a proportion correct from 0 to 1, whereas PFB and IB are measured on five-point Likert scales.

4.5 *Correlation analysis*

Pearson correlation analysis was conducted to examine the relationships among the study variables (Table 5).

Table 5. Pearson correlation matrix

Variable	FL	PFB	IB
Financial literacy (FL)	1	0.668**	0.589**
Perceived parental financial behaviour (PFB)	0.668**	1	0.808**
Investment behaviour (IB)	0.589**	0.808**	1

Note: **p < 0.01, two-tailed. Source: SPSS output.

All three variables were positively and significantly correlated.

Financial literacy had a moderate positive correlation with investment behaviour ($r = 0.589$, $p < 0.01$). This result provides initial support for H1 and is consistent with previous research suggesting that financial knowledge can facilitate informed investment decisions [2], [12], [13].

Perceived parental financial behaviour had a stronger positive correlation with investment behaviour ($r = 0.808$, $p < 0.01$). This indicates that respondents who reported more positive parental financial behaviour also tended to report more active investment behaviour.

Financial literacy and perceived parental financial behaviour were also positively correlated ($r = 0.668$, $p < 0.01$). This finding is consistent with the wider financial socialization literature, which suggests that financial experiences within the family may be related to financial knowledge [8]-[10]. However, the present study does not interpret this correlation as evidence that PFB causes financial literacy because that pathway was not separately modelled.

4.6 *Multiple regression analysis*

Multiple regression was used to examine whether financial literacy and perceived parental financial behaviour jointly explain variation in investment behaviour. Because FL and PFB were correlated ($r = 0.668$), multicollinearity was considered. Based on the correlation between the two predictors, the variance inflation factor (Equation 2) is approximately:

$$VIF = 1 / (1 - 0.668^2) = 1.81 \quad (2)$$

This value is substantially below commonly used thresholds of 5 or 10 [24], suggesting that multicollinearity between the two predictors is not a serious concern.

Table 6 presents the model summary.

Table 6. Regression model summary

R	R^2	Adjusted R^2	Std. Error of Estimate
0.814	0.662	0.659	0.374

Source: SPSS output.

Table 7. ANOVA

Source	Sum of Squares	df	Mean Square	F	Sig.
Regression	50.391	2	25.195	180.485	<0.001
Residual	25.686	184	0.140		
Total	76.077	186			

Source: SPSS output.

Table 8. Regression coefficients (dependent variable: investment behaviour)

Predictor	B	Std. Error	β	t	Sig.
Constant	0.392	0.379	–	1.035	0.302
Financial literacy	0.942	0.416	0.100	2.266	0.025
Perceived parental financial behaviour	0.684	0.039	0.782	17.632	<0.001

Source: SPSS output.

The regression model produced an R value of 0.814 and an R^2 of 0.662. Thus, financial literacy and perceived parental financial be-

haviour jointly explained 66.2% of the observed variance in investment behaviour.

The adjusted R^2 of 0.659 indicates that the explanatory power remains high after adjusting for the number of predictors included in the model.

Table 7 presents the ANOVA results.

The overall regression model was statistically significant, $F(2,184) = 180.485$, $p < 0.001$. Therefore, the two predictors, considered jointly, provide significant explanatory information about investment behaviour.

Table 8 presents the regression coefficients.

The estimated regression equation is given in Equation 3:

$$IB = 0.392 + 0.942FL + 0.684PFB \quad (3)$$

Both predictors were positive and statistically significant.

Financial literacy had a positive coefficient ($B = 0.942$, $p = 0.025$). Because FL is measured from 0 to 1, a 0.10 increase in the financial literacy score is associated with approximately a 0.094-point increase in the investment behaviour score, holding PFB constant.

The standardized coefficient for financial literacy was relatively small ($\beta = 0.100$). This should not be interpreted as evidence that financial literacy is unimportant. The financial literacy variable had very limited variation, with a mean of 0.930 and SD of only 0.068. The high concentration of finance-trained respondents may therefore have restricted the statistical variation available to explain differences in investment behaviour.

Perceived parental financial behaviour had a considerably stronger association with investment behaviour. Its coefficient was positive and statistically significant ($B = 0.684$, $\beta = 0.782$, $p < 0.001$). Holding financial literacy constant, a one-unit increase in perceived parental financial behaviour was associated with an estimated 0.684-point increase in the investment behaviour score.

The standardized coefficient indicates that PFB was the stronger predictor in the model. However, because the research design was cross-sectional, these coefficients should be interpreted as statistical associations rather than causal effects.

4.7 *Hypothesis testing*

Table 9 summarises the results of the hypothesis tests.

For H1, financial literacy had a positive and statistically significant relationship with investment behaviour ($\beta = 0.100$, $p = 0.025$). Therefore, H1 is supported.

For H2, perceived parental financial behaviour had a positive and statistically significant relationship with investment behaviour ($\beta = 0.782$, $p < 0.001$). Therefore, H2 is also supported.

The results therefore support the proposed two-predictor model. They do not, however, establish a PFB - FL pathway because that relationship was not included as a hypothesis or tested through regression or mediation analysis.

Table 9. Summary of hypothesis testing

Hypothesis	Relationship	β	p-value	Decision
H1	Financial literacy - Investment behaviour	0.100	0.025	Supported
H2	Perceived parental financial behaviour - Investment behaviour	0.782	<0.001	Supported

Source: SPSS output.

5 DISCUSSION

The findings provide two important insights into the investment behaviour of young adults in the Western Province.

First, financial literacy was positively and significantly associated with investment behaviour. This finding is consistent with earlier research showing that financial knowledge is related to investment participation and decision-making [1], [2], [12]. It is also consistent with more recent evidence from emerging markets showing that financially literate individuals are more likely to make informed investment decisions [13].

However, the relatively small, standardized coefficient for financial literacy ($\beta = 0.100$) needs careful interpretation. The result should not be taken to mean that financial literacy has little practical value. Instead, the statistical result is likely influenced by the characteristics of the sample. Financial literacy was extremely high, with a mean of 0.930, and variation was limited. In addition, 84.5% of respondents were

Finance majors. When almost all respondents possess relatively high financial knowledge, there is less variation available to distinguish differences in investment behaviour.

This is an important contribution of the study. The results suggest that once a basic level of financial knowledge is already present, other factors may become more important in explaining differences in investment behaviour.

Second, perceived parental financial behaviour showed a substantially stronger association with investment behaviour than financial literacy. The standardized coefficient for PFB was $\beta = 0.782$ compared with $\beta = 0.100$ for financial literacy. This finding is consistent with the financial socialization literature, which emphasises the importance of family experiences in shaping financial attitudes and behaviours [5], [6].

The finding is also consistent with more recent evidence. Chawla, Bhatia and Singh [8] identified parental financial behaviour as an important factor in young adults' financial development. Owusu et al. [9] similarly reported that parental financial behaviour was associated with young adults' savings and investment behaviour. Studies from India have also shown that parental financial socialization can contribute to financial literacy, financial self-efficacy and financial behaviour [10], [11], [19].

One possible explanation is that financial behaviour is learned through repeated exposure. A young adult may learn about saving or investment from a textbook, but observing parents save, compare financial products, discuss financial risks or plan for future needs may provide a more concrete behavioural model. This interpretation is consistent with Social Learning Theory [7].

The strong PFB-IB relationship also has to be interpreted carefully. The correlation between the two variables was 0.808, which is high. Both variables were measured through self-reported responses from the same individual and at the same time. Consequently, common-method bias may have contributed to the strength of the observed relationship. For example, respondents who are personally active investors may also have a more favourable perception of their parents' financial behaviour. The present design cannot separate these possibilities.

The positive correlation between PFB and FL ($r = 0.668$) is also theoretically interesting. Previous studies have reported that parental financial socialization can influence financial literacy [8]-[10]. However, the present study deliberately does not interpret this association as a tested causal pathway. Doing so would require a separate model in which PFB predicts FL and, ideally, a mediation analysis examining whether FL transmits part of the relationship between PFB and IB.

The findings also have practical implications. Financial education programmes for young adults often focus primarily on delivering financial knowledge. The present results suggest that this approach may be strengthened by recognising the family environment in which financial behaviour develops. Financial education initiatives could therefore include family-oriented components, such as encouraging parents to discuss saving, investment risk, budgeting and long-term financial planning with their children.

For universities and financial institutions, this means that financial education should not only ask whether young adults understand financial concepts. It should also consider whether young adults have opportunities to observe and practise appropriate financial behaviours. For families, the results highlight that everyday financial practices may themselves become a form of informal financial education.

Nevertheless, the results should not be interpreted as demonstrating that parental financial behaviour is more important than financial literacy for all young adults. The present sample is unusually concentrated among finance-trained respondents, and the study is limited to one province. A more diverse national sample may produce a different balance between the two predictors.

6 CONCLUSION

This study examined the relationships between financial literacy, perceived parental financial behaviour and investment behaviour among young adults aged 20-29 in the Western Province of Sri Lanka.

The results provide evidence that both financial literacy and perceived parental financial behaviour are positively and significantly associated with investment behaviour. The two predictors jointly explained 66.2% of the variance in investment behaviour.

However, perceived parental financial behaviour showed a substantially stronger standardized association with investment behaviour ($\beta = 0.782$, $p < 0.001$) than financial literacy ($\beta = 0.100$, $p = 0.025$).

The findings reinforce the idea that financial development among young adults is not solely a matter of financial knowledge. The financial environment in which young people grow up may also matter. Parents can act as financial role models, and repeated exposure to saving, investment and responsible money management may influence the way young adults approach their own financial decisions.

At the same time, the results should be interpreted within the limitations of the study. The final sample consisted of 187 respondents, which is smaller than the commonly cited sample-size benchmark of 384 for large populations. The use of non-probability convenience sampling also limits statistical generalisability. In addition, the sample was heavily concentrated among respondents aged 25-29 and, particularly, among Finance majors. This may partly explain the very high financial literacy scores and the limited variation in the literacy variable.

The geographical focus on the Western Province is another limitation. Although the province is an important financial and commercial centre and provides substantial exposure to financial services, young adults in other provinces, particularly rural areas, may face different financial opportunities, constraints and social influences. Therefore, the findings should not be generalised automatically to all young adults in Sri Lanka.

The cross-sectional design also prevents causal conclusions. The observed relationships indicate associations between the variables but cannot establish that parental financial behaviour causes investment behaviour or that financial literacy causes investment behaviour.

Future research should therefore extend the analysis using larger and more geographically diverse probability samples. Studies should also include greater representation of non-finance students and young adults outside the university sector. A particularly important direction for future research is to test whether perceived parental financial behaviour influences investment behaviour directly and indirectly through financial literacy. Such a relationship could be examined using mediation analysis or structural equation modelling. Future studies could also include financial confidence, risk tolerance, peer influence, digital financial experience and investment experience as additional explanatory variables.

Overall, the study provides evidence that both formal financial knowledge and informal financial learning within the family are relevant to young adults' investment behaviour. The findings therefore support a broader approach to financial education in which financial literacy programmes are complemented by attention to the family environment in which financial habits are developed.

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Towards an AI-Era Human Resource Competency Framework for Sri Lanka's Private Sector: A Literature-Driven Conceptual Model and Empirical Validation Agenda

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ABSTRACT: Human resource (HR) competency frameworks translate the abstract demands of "good HR practice" into observable, trainable behaviours, yet no published framework specifically models the competencies expected of private-sector HR professionals in Sri Lanka. Meanwhile, artificial intelligence (AI), people analytics, hybrid work and a multigenerational workforce are reshaping what HR professionals must know and do, faster than institutional competency models such as SHRM's Body of Applied Skills and Knowledge, the CIPD Profession Map and the Ulrich/RBL HR Competency Study can be revised. This conceptual paper synthesizes post-2020 global and regional literature on HR competencies to construct a candidate competency pool for Sri Lankan private-sector HR professionals, using a transparent literature-convergence coding scheme across six source clusters. Twenty-six competencies are organized into six clusters (strategic/business, digital/analytical, relational/interpersonal, ethical/governance, personal/adaptive and technical/functional) and screened for theoretical importance rather than empirical prevalence. Several competencies with limited convergence across established frameworks – including AI governance stewardship, paradox navigation, statutory literacy and cross-generational leadership – are retained and defended as theoretically important departures from the popular understanding of HR competency. The paper closes by proposing a dual-rater (self and coworker), weighted-proficiency empirical methodology, adapted from a recent Sri Lankan competency-framework study, for testing and refining this framework in a subsequent full-scale study. No primary data were collected; the competency pool constitutes a set of literature-derived hypotheses for empirical validation.

Keywords: HR competency framework, competency modelling, Sri Lanka, South Asia, artificial intelligence in HR, Generation Z, people analytics

1 INTRODUCTION

Competency frameworks have become, in Bartram's words, close to a common language for human resource systems, translating strategic intent into observable, hireable, trainable behaviour [1]. Well-constructed frameworks require iterative testing, weighting of importance and trainability, and contextual grounding in the industry and country of use [2].

The HR profession itself is unusual: it builds competency frameworks for everyone else in the organization, yet its own competency base is now under strain. Artificial intelligence and algorithmic decision-making

are reshaping recruitment, performance management and workforce planning [3], exposing HR professionals who lack digital and analytical fluency [4]. Generation Z's entry into the workforce, accelerated by post-pandemic expectations of flexibility, purpose and psychological safety, is forcing a re-examination of engagement and reward competencies that pre-date this cohort [5], [6]. Meanwhile, HR functions in South Asia operate within statutory, collectivist and socio-cultural conditions that differ materially from the Anglo-American contexts in which most global competency models originate [7].

Despite this, no published, empirically grounded competency framework exists for HR professionals in Sri Lanka's private sector. Adjacent Sri Lankan competency-framework research exists for other roles – for example, site administrative officers in construction [8] – but none has yet been produced for the HR profession itself, despite HR being the function best placed methodologically to produce one.

This paper addresses that gap in three stages. First, it synthesises post-2020 global institutional and peer-reviewed literature on HR competencies – spanning SHRM, CIPD, Ulrich/RBL and emerging literature on AI, people analytics and generational change – into a candidate competency pool. Second, it applies a transparent literature-convergence coding scheme to theoretically prioritise the pool, explicitly identifying competencies that depart from the popular, framework-consensus understanding of HR competency. Third, it proposes a concrete empirical methodology, adapted from a recent Sri Lankan competency-framework study [8], for testing this model with practising HR professionals in a subsequent full-scale study.

2 LITERATURE REVIEW

2.1 *Competency and Competency Frameworks: Conceptual Foundations*

Competency is best understood as the underlying characteristics – knowledge, skill, self-concept, trait and motive – that predict effective or superior job performance [9]. A competency framework operationalizes this by specifying which competencies matter for a role, at what proficiency level, and how they are observed through behavioural indicators [1], [10]. Two lessons recur across recent competency-framework studies: frameworks gain utility when weighted by both contribution to successful performance and difficulty to improve, rather than treated as equally important or trainable [2], [8]; and frameworks travel poorly across contexts unless empirically re-tested in the population and industry to which they will be applied [8].

2.2 *Global HR Competency Models*

Three institutional models dominate the global HR competency landscape. SHRM's Body of Applied Skills and Knowledge (SHRM BASK), revised in 2021, defines nine behavioural competencies – HR expertise, ethical practice, business acumen, consultation, critical evaluation, communication, relationship management, global and cultural effectiveness, and leadership and navigation [11]. CIPD's Profession Map, developed with input from around 20,000 people professionals, structures competency around core knowledge (people practice, culture and behaviour, business acumen, analytics and creating value, digital working, and change), core behaviours (ethical practice, professional courage and influence, valuing people, working inclusively, passion for learning, insights-focused, situational decision-making, and commercial drive) and role-selected specialist knowledge [12]. The Ulrich/RBL HR Competency Study (HRCS), now in its eighth round, empirically derives nine competency domains from tens of thousands of multi-rater responses, organized around three core drivers – strategic positioner, credible activist and paradox navigator – and six enablers spanning culture and change, human capital, total rewards, technology, analytics and compliance [13], [14]. The evolution of HR competency modelling beyond these three institutional frameworks has itself been the subject of academic interest, tracing a shift from functional, transactional HR competencies toward more strategic ones over the past two decades [15].

These three frameworks converge strongly on business acumen, ethical practice, communication and change leadership. They diverge on tension-management (paradox navigator, unique to Ulrich/RBL), digital working as an explicit core-knowledge domain (CIPD), and whether analytics is a dis-

crete competency or embedded within critical evaluation (SHRM). None was designed with South Asian statutory or socio-cultural conditions, nor the post-2022 acceleration of generative AI, as a primary reference point.

2.3 *Disruptive Forces Reshaping HR Competency Demands After 2020*

AI and digital transformation. A systematic review of AI's competency demands on HR managers found that technical data-analysis skills must be paired with "institutional configuration capability" – leading digital-transformation change while remaining a credible people-facing partner [4]. A parallel systematic review of AI and automation in HR development concludes that HR professionals need new competencies in overseeing algorithmic fairness and reskilling the workforce, rather than simply operating new software [3]. Budhwar et al.'s review of AI in international HRM highlights persistent gaps in understanding of algorithmic bias, explainability and data governance – competencies barely represented in pre-2020 frameworks [16].

People analytics. Despite HR leaders widely endorsing analytics as central to HR's future, a 2023 industry survey found people analytics and data-driven decision-making to be HR's single largest skills gap across career levels [17], echoed in recent scoping reviews of people analytics from an HR development perspective, which identify persistent under-investment in statistical and data-storytelling capability [18], [19]. A rigorous, empirically-derived competency model for the emerging HR analyst role, built from job-advertisement analysis and practitioner interviews, similarly finds technical/analytical skill insufficient without accompanying business acumen and communication competency [20], directly paralleling this paper's own People Analytics & Evidence-Based Decisions and Digital Communication Agility items.

Generational and post-pandemic change. Conceptual work on Generation Z's entry into the post-COVID-19 workplace argues that established engagement and retention competencies must be supplemented with purpose-alignment, psychological safety and flexible-work design – secondary concerns in earlier models [5]. Related work on building a post-pandemic-resilient Generation Z workforce similarly foregrounds well-being stewardship and coaching-style leadership as competencies whose relative importance has risen sharply since 2020 [6].

2.4 *HR Competency Research in South Asia and Sri Lanka*

A regional synthesis of HRM practice across six South Asian countries – Bangladesh, India, the Maldives, Nepal, Pakistan and Sri Lanka – found that HRM in the region is simultaneously converging with, and diverging from, Western practice, shaped by distinctive statutory regimes, collectivist social structures, and a large informal-economy interface that Western competency models do not address [7]. Within Sri Lanka specifically, competency-framework research exists for adjacent roles – notably a study developing an evidence-based framework for construction-site administrative officers using a weighted proficiency-rating (WPR) methodology combining desired/actual/gap analysis, contribution-to-performance and difficulty-to-improve scoring [8] – but no equivalent study has yet been conducted for the HR profession itself, despite HR practitioners operating under exactly the statutory and socio-cultural conditions the regional literature identifies as under-represented in global models [7].

3 LITERATURE-SYNTHESIS METHODOLOGY

This paper is a conceptual and review contribution, without empirical claims. The competency pool below was constructed through a purposive, framework-triangulation synthesis rather than a formal PRISMA-style systematic review, consistent with the literature-plus-panel-convergence approach used in comparable recent competency-framework studies [2], [21], [8]. Search sources comprised: (i) the three institutional frameworks in Section 2.2 [11], [12], [13], [14]; (ii) post-2020 journal literature on AI, digital transformation and people analytics [3], [4], [16], [18], [19], [20]; (iii) literature on generational and post-pandemic workforce change [5], [6]; and (iv) South Asian and Sri Lankan HRM literature [7], [8]. Pre-2020 sources were retained only where they anchor a still-current institutional framework – e.g., the 2016/2017 Ulrich/RBL round underlying Round 8 [13],

[14], or Dreyfus's proficiency-staging model, still used in recent competency-scoring methodologies [22], [8]. Consistent with its stated aim as a conceptual synthesis rather than a systematic review, this identification process was not conducted as a registered, reproducible database query with a documented search string or a PRISMA-style screening count; it reflects the authors' purposive judgement of relevance, a boundary made explicit as a limitation in Section 7.

Each competency was coded against six source clusters: SHRM BASK (S), CIPD Profession Map (C), Ulrich/RBL HRCS (U), post-2020 AI/digital-HR literature (A), generational/post-pandemic workforce literature (G), and South Asian/Sri Lankan regional literature (R). A competency's convergence count – the number of clusters in which it is independently identified – is reported in Table 1, in place of the empirically-derived "contribution to successful performance" (CSP) score used in comparable Sri Lankan studies [8]; it functions analogously, as a provisional importance signal to be replaced by empirical CSP scoring in the follow-up study proposed in Section 6. Low-convergence competencies were not discarded automatically; several are retained and defended in Section 5 precisely because their theoretical justification appears strong even where not yet reflected in institutional consensus. The convergence count should accordingly be read as a heuristic literature-synthesis indicator, reflecting the authors' own classification of the reviewed sources, rather than an empirical or independently validated measure of competency importance; no formal inter-rater reliability check was conducted on the coding.

3.1 *Conceptual Model*

Figure 1 summarises how the four contextual drivers identified in the literature above – AI and digital transformation, generational and post-pandemic workforce change, South Asian statutory and socio-cultural context, and changing work arrangements – are hypothesized to shape the six competency clusters in Table 1. They are in turn hypothesized to influence HR effectiveness and organizational outcomes. This model is not tested in the present paper; it is offered as an explicit statement of the causal logic underlying the taxonomy, to be examined alongside the competency pool itself in the empirical study proposed in Section 6.

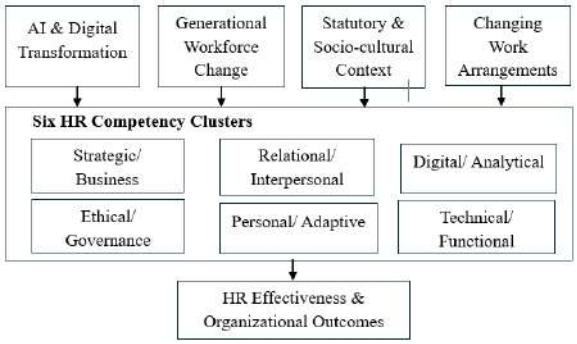


Figure 1. Proposed conceptual model linking contextual drivers to HR competency clusters and hypothesized organizational outcomes

4 PROPOSED HR PROFESSIONAL COMPETENCY TAXONOMY

Table 1 presents the resulting pool of 26 competencies for private-sector HR professionals in Sri Lanka, organized into six clusters: strategic/business-alignment; digital/analytical; relational/interpersonal; ethical/legal/governance; personal/adaptive; and HR technical/functional expertise. This structure mirrors, without exactly replicating, the personal/social competency-group architecture used in adjacent Sri Lankan competency research [8], while foregrounding the digital, ethical-AI and generational-leadership competencies from Section 2.3 as clusters in their own right. Source-cluster codes follow Section 3: S = SHRM BASK, C = CIPD Profession Map, U = Ulrich/RBL HRCS, A = post-2020 AI/digital-HR literature, G = generational/post-pandemic workforce literature, R = South Asian/Sri Lankan regional literature. Four digitally-adjacent competencies – AI Fluency, AI Governance, HR Technology Stewardship, and Data Privacy Stewardship – and two strategic/adaptive pairs – Business Acumen/Strategic Workforce Positioning and Adaptability/Paradox Navigation – are deliberately differentiated rather than merged; Table 1's indicator wording is written to keep each pair conceptually distinct.

Table 1. Proposed HR professional competency taxonomy for Sri Lanka's private sector, with literature-convergence codes and counts (max. 6)

Competency (Cluster)	Illustrative Behavioural Indicator	Convergence (codes / count)
1. Business Acumen (Strategic)	Translates business/market drivers into workforce decisions.	S,C,U,R / 4
2. Strategic Workforce Positioner (Strategic)	Translates business strategy into future workforce architecture and talent plans.	C,U / 2
3. Change Leadership (Strategic)	Leads and embeds change and culture transformation.	C,U / 2
4. Paradox Navigation (Strategic)	Knowingly reconciles two competing goods (e.g., cost vs. care), not just coping with ambiguity.	U / 1
5. People Analytics & Evidence-Based Decisions (Digital)	Uses workforce data to diagnose problems and justify decisions.	C,U,A / 3
6. AI Fluency & Algorithmic Literacy (Digital)	Knows what AI-enabled HR tools can/cannot do; does not itself govern their use.	A / 1
7. AI Governance & Ethics Stewardship (Digital)	Governs how AI is used in people decisions: fairness, transparency, bias-mitigation.	A / 1
8. HR Technology Stewardship (Digital)	Configures/administers the broader HR technology stack (HRIS, payroll, ATS), AI included.	C,U,A / 3
9. Digital Communication Agility (Digital)	Communicates effectively across hybrid/remote channels.	A,G / 2
10. Trust-Building / Credible Activism (Relational)	Builds credibility through consistent, principled action.	S,U / 2
11. Cross-Generational Leadership (Relational)	Adapts coaching/feedback style across generational cohorts.	G / 1
12. Cultural & Social Sensitivity (Relational)	Works effectively across South Asia's ethnic/religious/linguistic diversity.	R,S / 2
13. Conflict Mediation & Negotiation (Relational)	Resolves workplace and industrial-relations disputes fairly.	S,R / 2
14. Inclusive Communication (Relational)	Listens actively; adapts message to diverse audiences.	S,C / 2
15. Ethical Practice & Integrity (Governance)	Upholds confidentiality, fairness and professional standards.	S,C / 2
16. Statutory & Labour Law Literacy (Governance)	Applies local employment law (EPF/ETF, termination, disputes).	R / 1
17. Data Privacy Stewardship (Governance)	Protects confidentiality/security of employee data, distinct from AI Governance's fairness focus.	A,C / 2
18. Compliance Management (Governance)	Ensures HR practice meets regulatory/audit requirements.	U / 1
19. Continuous Learning Agility (Adaptive)	Proactively updates own skills as technology/market shifts.	C,A / 2
20. Resilience & Stress Tolerance (Adaptive)	Sustains performance and composure under pressure.	S,G / 2
21. Emotional Intelligence & Self-Awareness (Adaptive)	Recognises and regulates own and others' emotions.	S,C,G / 3
22. Adaptability to Ambiguity (Adaptive)	Functions effectively amid incomplete information, rapid change.	U,A / 2
23. Talent Acquisition & Employer Branding (Technical)	Attracts the right talent, including for gig/hybrid roles.	S,G / 2
24. Total Rewards & Well-Being Design (Technical)	Designs reward/well-being propositions valued across generations.	U,G / 2
25. Learning & Capability Building (Technical)	Builds capability, including reskilling for automation.	S,C,A / 3
26. Performance & Productivity Enablement (Technical)	Balances accountability with a growth mindset.	S,U / 2

5 DISCUSSION: DEPARTURES FROM THE POPULAR UNDERSTANDING OF HR COMPETENCY

Table 1 shows a skewed convergence distribution: five competencies (19%) converge across three or more source clusters, fifteen (58%) converge across exactly two, and six (23%) are identified in only a single cluster. The five high-convergence competencies – Business Acumen, People Analytics & Evidence-Based Decisions, HR Technology Stewardship, Emotional Intelligence & Self-Awareness, and Learning & Capability Building – correspond closely to the popular, SHRM/CIPD/Ulrich-consensus understanding of HR competence. The six single-cluster competencies are treated separately below: three are single-cluster for essentially definitional reasons, and three are retained as theoretically consequential departures from institutional consensus.

AI Governance & Ethics Stewardship has no direct counterpart in SHRM BASK, CIPD's Profession Map or the current Ulrich/RBL model, all of which pre-date or only partially absorb the generative-AI literature of 2022 onward. Its inclusion rests on convergent findings that HR professionals are already accountable for algorithmic fairness, explainability and data governance in AI-assisted decisions, whether or not their training has caught up [3], [4], [16]. Given the rapid diffusion of AI-enabled HR tools even in organizations without formal AI governance policy, treating this as a peripheral sub-skill of "HR expertise" understates the risk it manages.

Paradox Navigation, present only in the Ulrich/RBL model [13], [14], is retained as a distinct competency rather than folded into "adaptability", because the AI and generational literature each surface new instances of this tension – algorithmic efficiency versus human judgement, or flexible, purpose-driven Gen Z expectations versus operational discipline – that older frameworks did not anticipate needing to reconcile simultaneously [3], [5].

The remaining three single-cluster competencies – AI Fluency & Algorithmic Literacy, Cross-Generational Leadership, and Compliance Management – are single-cluster for a more mundane reason than theoretical novelty, and are distinguished here from the three discussed above and below. AI Fluency and Cross-Generational Leadership are, in effect, definitionally confined to their respective literature: competency about AI-tool capability can only be surfaced by AI-focused literature, and a competency about generational cohorts can only be surfaced by generational-workforce literature. Compliance Management's single-cluster status is better read as a labelling difference than a substantive gap: SHRM and CIPD distribute compliance-related behaviour across "ethical practice" and general "core knowledge" rather than naming it as a discrete competency, whereas Ulrich/RBL names it explicitly. These three items are retained in Table 1 for completeness but are not treated as evidence of a gap in institutional consensus in the way the three competencies discussed here are.

Statutory & Labour Law Literacy is the only governance-cluster competency identified in a single source cluster (R). It has no standalone counterpart in SHRM, CIPD or Ulrich/RBL, likely because those frameworks were developed primarily from North American and Western European samples. The South Asian regional literature, however, identifies statutory complexity, collectivist social structure and a large informal-economy interface as defining, not incidental, features of the HR role in the region [7] – consistent with the country-specific demands documented in adjacent Sri Lankan competency research [8]. Elevating this to core-competency status reflects the regional literature more faithfully than direct adoption of a Western framework would.

Cultural & Social Sensitivity converges across two clusters (R, S) rather than one, but neither is an institutional "big three" framework: it is present in SHRM's broad "global and cultural effectiveness" item and in the South Asian regional literature, but absent from CIPD and Ulrich/RBL. Its retention as a distinct competency, rather than a sub-item of communication or business acumen, reflects the same regional literature as Statutory & Labour Law Literacy, even though its convergence profile is less extreme.

Perhaps the most consequential departure is a deliberate non-inclusion: popular understanding of HR competency, reinforced by decades of SHRM/CIPD framing, treats HR-process administration – payroll, leave ad-

ministration, records management – as foundational "HR knowledge". The post-2020 AI/automation literature suggests this is precisely the layer of HR work being automated fastest [3], [4], a pattern a recent review of robotic process automation in HR specifically confirms, identifying payroll processing, leave administration, onboarding and compliance reporting as the HR sub-processes most amenable to automation [23], so retaining it as a standalone core competency risks anchoring training and recruitment priorities to work being progressively displaced. This taxonomy folds transactional administration into "HR Technology Stewardship" (competency 8), reframing the underlying skill as configuring and governing the systems that perform administration, rather than performing it manually – an intentional and, it is argued here, defensible departure that should be tested, not assumed, in the empirical study proposed in Section 6.

6 METHODOLOGY

The taxonomy in Table 1 constitutes literature-derived hypotheses; it has not been tested against the judgement of practising HR professionals and should not be treated as an empirical finding. This section proposes a concrete design, adapted from a recent Sri Lankan competency-framework study [8], for a subsequent full-scale empirical paper.

Instrumentation. Following the Cycloid-style, single-statement behavioural-indicator format used in adjacent competency research [8] each of the 26 competencies would be operationalised as one first-person statement, rated on a 1–5 Likert scale for both actual and desired behaviour. Proficiency would be scored against Dreyfus's five-stage novice-to-expert model, consistent with its use in comparable methodologies [22], [8]. Formally, for competency i,

$$WPRi = CSPi \times DIi \times PRi,$$

where CSP_i is the empirically-derived contribution-to-successful-performance score (from desired/actual/gap ranking, scored 1–3), DI_i is the expert-panel difficulty-to-improve score (1–3), and PR_i is the mean Dreyfus proficiency rating (1–5) across self- and coworker raters – directly following the method demonstrated for an adjacent Sri Lankan role [8].

Eligibility criteria. Eligible respondents are HR professionals currently employed in a private-sector organization registered or operating in Sri Lanka, in any HR role from executive to CHRO, with a minimum of one year of HR experience to support informed self-rating. Each respondent is asked to nominate one same-level coworker – not a supervisor or subordinate – who has observed their day-to-day HR behaviour for at least six months.

Dual-rater design – a deliberate modification. Where the precedent study paired self-ratings from administrative officers with supervisor ratings from project managers [8], this design substitutes a same-level coworker as the second rater, to reduce power-distance-related response bias plausible in supervisor-rated designs within Sri Lanka's comparatively high-power-distance organizational culture, and to capture how HR competence is perceived laterally rather than only hierarchically. Sri Lanka scores 80 on Hofstede's Power Distance Index, indicating a comparatively hierarchical society in which subordinates are less likely to rate a superior candidly [24]; a recent study of Sri Lankan professional settings confirms this dynamic empirically – albeit in an adjacent field, medical education, rather than HR specifically – finding that hierarchical position measurably shapes how openly individuals engage with those above them [25].

Coworker nomination procedure. After providing consent, respondents nominate a coworker by name; the nominated coworker is contacted separately, provides independent consent, and completes the coworker-rating instrument anonymously. Responses are paired using a respondent-generated code rather than names, so that neither party's individual ratings are visible to the other or to the respondent's employer.

Instrument development and pilot testing. The 26 behavioural-indicator statements will be piloted with 5–8 HR professionals using cognitive interviewing to check clarity, length and face validity, with wording revised accordingly. A small pilot administration ($n \approx 15–20$) will then assess completion time and preliminary reliability before the main data collection round. Given this paper's own observation that non-English-language HR literature and practice are under-represented in the current synthesis

(Section 7), the instrument will also be translated into Sinhala and Tamil, with back-translation used to check equivalence.

Content validity and reliability. Content validity will be assessed by convening a panel of 5–7 senior HR practitioners and academics to rate each competency's relevance and clarity, following Lawshe's content validity ratio (CVR) method; items falling below the panel-size-appropriate CVR threshold will be revised or dropped before the main round. Internal consistency will be assessed via Cronbach's alpha within each of the six competency clusters, and self–coworker agreement via the intraclass correlation coefficient (ICC).

Sampling. The target population is private-sector HR professionals in Sri Lanka, best reached through HR professional bodies and cross-organizational networks. A convenience frame with quota targets across gender, generational cohort, and organization type/industry would approximate representativeness in the absence of a formal sampling frame. Both self- and coworker-rated proficiency scores will be reported; the mean of the two will serve as the primary proficiency estimate, but any competency showing a discrepancy of two or more points on the five-point scale between rater types will be flagged and reported separately rather than silently averaged, consistent with this paper's own argument that lateral and hierarchical perceptions of competence may genuinely differ.

Statistical analysis and retention criteria. Analysis will report descriptive statistics per competency; paired comparisons (Wilcoxon signed-rank, given the ordinal Likert data) between desired and actual ratings; WPR-based ranking; and subgroup comparisons (e.g., multinational vs. SME, generational cohort) via Kruskal–Wallis tests where subsample sizes permit. Consistent with the precedent study [8], competencies will be retained in the final framework if they appear among the top-ranked WPR competencies for both HR and coworker-rated groups; competencies with negligible empirical CSP in both groups will be flagged as candidates for merging or removal in a subsequent validation round, with this decision rule stated here in advance rather than applied post hoc.

7 CONCLUSION

This paper is explicitly conceptual: the competency pool and convergence coding in Table 1 reflect the authors' literature-based judgement. The search was purposive and rather than a systematic database search with a documented protocol. It relies predominantly on English-language, Scopus-indexed and institutional sources. not predominantly as a systematic search interface. Therefore, no database-level search string, screening count, or coder-agreement statistics can be reported for the synthesis as a whole. Practitioner literature in local language and unpublished Sri Lankan organizational frameworks were not considered and may surface additional, locally specific competencies not captured here. The taxonomy should be treated as provisional hypotheses pending the empirical study proposed in Section 6.

Global HR competency frameworks – SHRM's BASK, CIPD's Profession Map and the Ulrich/RBL HRCS – remain the dominant reference points for HR competency, yet none was built with post-2020 AI diffusion, Generation Z's workforce entry, or South Asian conditions as a primary design input, and none has been empirically tested against Sri Lankan private-sector HR professionals.

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Strategic Pathways for Circular Economy Integration in End-of-Life Electric Vehicle Batteries: A Thematic Analysis of Technological, Policy, and Supply Chain Interventions

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ABSTRACT: This research paper focuses on examining the possible ways of incorporating circular economy concepts in end-of-life (EoL) EV battery management based on a qualitative and expert-based thematic analysis approach. As far as the number of EVs increases rapidly, there is an increased amount of EoL lithium-ion batteries that require special management measures. In order to fill the gaps within the existing literature, this paper uses an interdisciplinary approach by collecting expert opinions from 12 specialists working within academic, business, government and sustainability-related fields. Based on a six-stage thematic analysis process, it comes up with five main areas influencing sustainable EoL battery management: the integration of circular economy concepts, advanced recycling and resources recovery, digitalization and smart monitoring, regulation and legislation, as well as supply chain and infrastructure systems. In this way, the research paper highlights the importance of using second life applications, innovations in recycling processes and digital technologies in the context of sustainable EoL battery management, while at the same time stressing some important barriers that may prevent their effective application (i.e. costs, lack of required infrastructure, absence of necessary policies, etc.).

Keywords: Circular Economy, End of Life EV Batteries, Lithium-ion Battery Management, Sustainable Recycling, Regulatory Frameworks

1 INTRODUCTION

As the world trend is to move to low-carbon energy systems, there is an acceleration in the transition to the use of electric vehicles (EVs) and as a result of it lithium-ion batteries (LIBs) are playing a major role as a critical enabler of sustainable mobility and integration of renewable energy sources [1],[8]. As increasing attention to climate change mitigation continues, the targets and policy interventions allow EV markets to grow exponentially and this open the doors to significantly more advanced energy storage systems getting deployed, at the same time, raising the alarm regarding the sustainability of battery lifecycles [1], [2]. Thus, the estimated increase in the end-of-life (EoL) batteries poses significant environmental, economical, and operational risks which need urgent and strategic considerations [1], [3].

It is known that LIBs have a high energy density, a long cycle life, and efficiency [2] but improper handling at EoL stage may cause serious environmental risks such as soil, water, and air pollution due to leakages of hazardous materials [4], [5]. According to the previous literature, there is a high probability of severe ecological degradation and a threat to the human health due to an inadequate level of waste management practices such as landfill and informal recycling practices that further stresses the need of controlled and sustainable waste management systems [4]. At the same time, the demand in the raw materials that require critical treatment, such as lithium, cobalt and nickel, continues to grow and it shows the necessity

of recovery of raw materials and their cyclic use to reduce the vulnerabilities of the supply chain and the environmental burden [1], [5].

As a result of the Circular Economy (EC), a paradigm shift has been established in the direction of developing an effective framework that will improve sustainability by implementing closed-loop systems that promote reuse, remanufacturing, and recycling [6]. One such circular approach that will facilitate both environmental and economic sustainability involves extending the life of batteries and minimizing reliance on virgin materials [6], [7]. However, due to their second-life applications, used EV batteries may be either recycled or reused less rigorously because stationary energy storage has become a major avenue for maximizing value and reducing lifecycle impacts [7], [8]. They discuss the opportunities for using second-life applications in conjunction with recycling to reduce greenhouse gas emissions and resource depletion compared to disposal or recycling alone [7].

Also, battery life management is also restructured by technological developments that have occurred within the sector. Through the application of blockchain technology, there has been an increase in terms of visibility and traceability, as well as better regulatory compliance across the battery value chain [3]. Also, through the use of technologies such as artificial intelligence (AI) and digital twinning, it becomes easier to manage processes involving battery life cycle, including predictive maintenance and real-time decision making in regards to battery life [9]. However, there are structures for lifecycle management which are associated with health and safety measures [10].

However, the current body of knowledge concentrates more on solving the fragmented issues like technology for recycling batteries [1], policy-making [3], or use after the endof-use life [8]. Such limitations restrict the development of a strategy that could be used to implement effective and sustainable management of batteries at their end of life. Due to the complex and cross-disciplinary nature of the electric vehicle battery ecosystem and the current focus of research literature on developing expert opinion based themes for managing EV batteries' life cycle sustainably, it is important to do so.

Upon this background, this study aims to develop an integrated strategic framework for sustainable end-of-life (EoL) electric vehicle battery management by examining expert insights on current challenges, circular economy applications, technological innovations, and the influence of policy, regulatory, and supply chain factors. Meanwhile the main research question stands as, “How can circular economy principles, technological innovations, policy and regulatory frameworks, and supply chain systems be strategically integrated to address challenges and enhance sustainability in end-of-life (EoL) electric vehicle battery management based on expert perspectives?”

Research Questions

Main: How can circular economy principles, technological innovations, policy and regulatory frameworks, and supply chain systems be strategically integrated to address the challenges and enhance sustainability of end-of-life (EoL) electric vehicle battery management, based on expert perspectives?

Sub:

SQ1: What role do circular economy strategies — second-life applications, reuse, and closed-loop recycling — play in extending the lifecycle value of EoL EV batteries, and what barriers limit their practical implementation?

SQ2: How do advanced recycling technologies and digitalization tools (AI, blockchain, predictive monitoring) contribute to more efficient and transparent EoL battery management, and what technological or economic constraints hinder their scalability?

SQ3: In what ways do policy, regulatory frameworks, and supply chain/infrastructure systems (reverse logistics, collection networks) enable or obstruct the effective coordination of sustainable EoL battery management?

2 LITERATURE REVIEW

2.1 *Growth of EV adoption and emerging eol challenges*

The dependence on the lithium-ion batteries (LIBS) is amplified with the swift worldwide acceptance of the electric vehicles (EVs) and the LIBs are known to be core enablers of the low-carbon energy transitions, high energy density, efficiency, and adaptability across transport and energy storage applications [2], [8]. This expansion

of utilization (through climate change policies and market demand) has significantly increased the number of end-of-life (EoL) batteries, posing major challenges to the environment and operation that must be addressed urgently driven [1], [3]. Issues with regard to retired batteries have led to a spurt in forecasts regarding waste management, resource recovery, and infrastructure preparedness [1], [5].

2.2 *Environmental risks and resource constraints*

The inappropriate disposal is one of the most concerned aspects in terms of environmental risks in EoL of LIBs. The majority of research shows that as a result of uncontrolled EoL practices, namely; landfilling, incineration or informal recycling, are contributing to the release of hazardous substances, leading to the contamination of soil, water and air [4], [5]. These increasing risks are further increased by the growing demands of the critical raw materials (lithium, cobalt and nickel) that are mostly resource intensive to extract and that are subject to the vulnerability of supply chains [1], [5]. This gives rise to the twofold task of reducing environmental damage and ensuring effective material recovery to enable sustainable battery ecosystems [1].

2.3 *Circular Economy and second-life applications*

As a result of the CE, one dominant framework has become a reality in addressing the battery lifecycle sustainability by promoting closed-loop systems that prioritize the use of reuse, remanufacturing, and recycling of the battery [6], [7]. It expounds the second-life applications of EV batteries, most notably the recycling of the batteries that have been retired by vehicular use, to less demanding applications, such as stationary energy storage systems, as EV batteries, most of which can still store 7080% of their original capacity [7], [8]. According to the studies conducted on the Life cycle assessment, integration of second-life utilization and recycling can significantly reduce the emissions and loss of resources as compared to direct disposal or isolated recycling methods [7]. However, challenges are abundant in terms of performance degradation, safety risks, and economic feasibility and continue to limit large-scale implementation of second-life systems [8].

2.4 *Recycling technologies and infrastructure limitations*

Through the advancement of recycling technologies, a lot of opportunities have emerged to improve material recovery and minimise environmental effects. In addition, methods such as hydrometallurgical and direct recycling methods, are distinguished by their capability to extract valuable metals more effectively and with less environmental footprints than conventional methods [1]. Nevertheless, even with these technological developments, prior literature discusses in-depth persistent hindrances, such as high costs of operations, technological complexity, and lack of adequate collection and processing infrastructure, which limit large-scale adoption [1], [3]. In addition, the uncoherent regulatory frameworks and the inaccessibility of standardized mechanisms to collect and track batteries still impede the efficacy of recycling networks [3].

2.5 *Digitalization and smart lifecycle management*

According to recent research, the transformative role in digital technologies is the one that makes the battery lifecycle management. The blockchain-based systems are primarily given an attention to enhance transparency, traceability, and accountability through the battery value chain by ensuring that data shared in a secure manner and lifecycle tracked [3]. At the same time, AI and digital twinnig makes it possible to monitor the battery health and EoL routing in real-time, predictively maintain, and make optimal decisions [9]. Nonetheless, these innovations are more facilitated by structured lifecycle management frameworks with key performance indicators, namely; state of health and safety, which preconditions the successful allocation of batteries along reuse, refurbishment and recycling pathways [10].

2.6 *Need for integrated and expert-driven perspectives*

Irrespective of the technological advancements, the current literature is still fragmented, as most of the studies are focussing

on areas such as recycling technologies [1], circular economy strategies [6], or digital innovations [9], despite of bringing into light the interconnected and multi-stakeholder nature of battery lifecycle systems. Nevertheless, the dynamic nature and context sensitivity of EV battery ecosystems, feeds more towards the significant uncertainty, restricting the applicability of the purely technical or model-based approaches [3], [10]. Consequently, numerous researches underline the significance of encompassing expert-based insights in order to comprehend the real-life issues, contextual differences, and strategic priorities that are not well represented in the current theoretical frameworks [3], [10]. Therefore, this study underscores the need for an expert perception–based approach to develop a more comprehensive and practice-oriented understanding of sustainable EV battery lifecycle management.

3 METHODOLOGY

The research employs the qualitative choice, using an expert perception methodology in exploring strategic approaches towards the end-of-life management of EV batteries. Given the complex nature of the issue, and its many stakeholders, the use of qualitative methods is most appropriate [11]. Data collection involved conducting semi-structured interviews on 12 experts. The group of 12 participants was selected on the basis of their professional knowledge and experience with regard to the electric vehicle (EV) batteries management, the concept of circular economy, sustainability, recycling and other related topics. The participants belonged to various professional groups, such as academia, industry, government/policy, and sustainability-related organization, which allowed the research to include various perspectives on the management of EoL EV batteries. In terms of professional diversity, the sample consisted of 4 academic professionals, 3 industry professionals, 3 government/policy professionals, and 2 sustainability/environmental professionals aged 30 to 55. All participants had more than 10 years of professional experience; they possessed knowledge about such aspects as batteries, recycling and resources recovery, circular economy practice, environmental sustainability, regulation and policy, and supply chain management. The sample also included participants from Western Province. The identity of the participants was kept private, and therefore the demographic data is presented anonymously. The diversity of professional backgrounds was deemed necessary for a holistic approach to sustainable EoL EV battery management. Sample size was limited to 12 due to reaching the saturation point [11], [12]. By conducting semi-structured interviews authors facilitated flexibility in exploring emerging themes and keeping up the consistency with the purpose of research [11]. Thematic analysis can be defined as a technique where the process involves identifying, analyzing, and interpreting themes in qualitative data [11]. Techniques such as data familiarization, coding, and thematic development were used. The qualitative data was analyzed using a six-stage systematic thematic analysis process carried out manually, including data familiarization, keyword selection, coding, thematic development, interpretation, and framework creation [12]. Descriptive codes and emerged themes are included in the appendices for reference (Table 2).

4 RESULTS AND DISCUSSION

Thematic analysis identified five themes explaining the Strategic Pathways for Circular Economy Integration in End-of-Life Electric Vehicle Batteries.

4.1 *RQ 1: Theme 1: Circular Economy Integration*

First, the study showed that integration into the circular economy was one of the most important steps in the management of electric vehicle batteries throughout their lifecycle, specifically second life use, reusing and closed-loop manufacturing and recycling. According to the specialists interviewed, electric vehicle batteries had significant residual value beyond their first-use application and could thus be recycled economically and sustainably. One of the respondents stated, "*It does not make sense to consider EV batteries as waste material after the battery has served its purpose. These batteries can actually be repurposed very effectively as stationary power storage."*

Reuse was another step towards sustainability and another participant said, *"By ex-*

tending the lifecycle through reuse, you can reduce the environmental impacts as well as the pressure on raw materials." A closed-loop production and consumption system allows for continuous circulation of the material used in the process, but several barriers to the practical implementation are there. One mentioned, *"So far there is no unified system for evaluating battery condition for the second-life use."*

4.2 *RQ2: Theme 2: Advanced Recycling and Resource Recovery*

Advanced recycling and recovery were seen as necessary factors in mitigating both environmental problems and the problem of material shortages. Specialists pointed to the need to recover such rare materials as lithium, cobalt, and nickel as necessary in order to decrease reliance on extracting them anew. *"Recycling is needed because these materials are too precious to be wasted at the end-of-life phase,"* one expert commented.

Some inherent drawbacks in current recycling processes are the inability to apply technological innovations efficiently, prohibitively high costs, and low scalability. One specialist stated, *"Surely advanced technologies for recycling do exist, but they cost too much to implement successfully."* Additionally, *"Unfortunately, not enough recycling centers have been constructed in many regions,"* another specialist commented.

4.3 *RQ2: Theme 3: Digitalization and Smart Monitoring*

Digitalization proved to be a technology with a significant influence on the lifecycle management of batteries of electric vehicles through AI-driven analytics, blockchain technology, and real-time monitoring systems. Many specialists stressed that digital solutions contribute to simplifying and optimizing the lifecycle management process. *"Through AI-driven analytics, we can predict battery degradation and decide on reuse or recycling of the battery."* Another technology identified was blockchain technology. Blockchain technology is can enhance reliability and accountability in the lifecycle process. One pointed out, *"Blockchain technology provides detailed information about battery usage and movement necessary for lifecycle management."* Finally, real-time monitoring systems are another solution that is essential for assessing the battery's state. However, the implementation of these technologies faced some challenges. Ex: *"Our team faces challenges related to high costs of implementation and a lack of technical skills in certain areas."*

4.4 *RQ3: Theme 4: Policy and Regulatory Frameworks*

Policy and regulation have played a significant role in shaping sustainable approaches towards battery management. They were crucial as per experts as they develop appropriate and responsible life-cycle management. One expert stated that *"Effective regulations and policies are crucial for encouraging industry players in adopting recycling and reusing practices, although it is important that they are enforceable."* Therefore, the importance of clear policies and regulation cannot be understated. There were several issues related to policies and regulations such as lack of adequate and clear standards, lack of enforcement, and insufficient incentives. For example, one participant argued that *"Although there are policies for managing the sustainability of batteries, they are not well-designed to direct the industry."* Thus, it is necessary to consider other aspects related to policy design and implementation as well. Another participant pointed out that *"Incentives and subsidies may promote use of sustainable technologies in batteries, although they need to be practical and accessible."*

4.5 *RQ3: Theme 5: Supply Chain and Infrastructure Systems*

Supply chains and infrastructure systems emerged as some of the most crucial factors in determining how effectively the end-of-life battery management can be carried out. In particular, reverse logistics, as well as collection and transportation processes, were noted by the participants as highly important to successful implementation of the strategies. The lack of proper infrastructure was stressed as the reason for inefficient end-of-life battery management. An expert noted: *"Without the collection infrastructure it is very hard to manage the batteries."*

The five themes can be interpreted as interconnected strategic pathways rather than

isolated interventions. Figure 1 synthesizes this relationship, while Table 1 consolidates the main strategic contribution and barriers identified through the expert interviews.

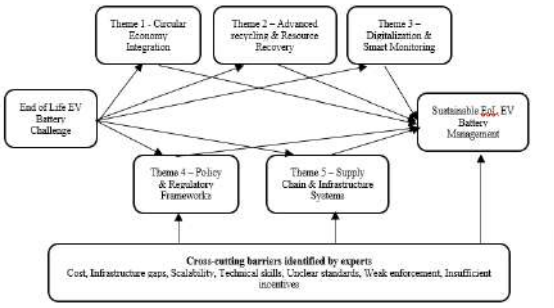


Figure 1. Integrated strategic pathways for sustainable EoL EV battery management

Note: Synthesized from the five themes identified through expert thematic analysis

Table 1. Summary of themes, expert evidence, and implementation barriers

Theme	Strategic contribution	Evidence reflected in results	Key barriers	Key Enablers
Circular economy integration	Second-life use, reuse and closed-loop approaches retain battery value and reduce pressure on virgin resources.	Residual value beyond vehicle use; stationary storage; lifecycle extension; need for battery-condition evaluation.	No unified second-life assessment system; performance degradation; safety and economic feasibility.	Standardized battery health assessment; second-life business models; testing and reconfiguration capabilities; closed-loop recovery systems.
Advanced recycling & resource recovery	Recovery of lithium, cobalt and nickel supports resource security and reduces environmental burdens.	Experts emphasized recovery of critical materials and the role of advanced recycling.	High implementation cost; technological complexity; low scalability; insufficient recycling centers.	Advanced recycling technologies; investment in recycling capacity; material-recovery expertise; processing facilities.
Digitalization & smart monitoring	AI, blockchain and real-time monitoring improve prediction, traceability, accountability, and routing decisions.	AI for degradation prediction; blockchain for battery history and movement; real-time state assessment.	High implementation costs; shortage of technical skills.	AI-driven analytics; blockchain traceability; real-time monitoring; battery data and digital lifecycle records; technical skills.
Policy & regulatory frameworks	Clear and enforceable rules, standards and incentives enable responsible lifecycle management.	Experts stressed enforceability, policy clarity and practical incentives.	Unclear/inadequate standards; weak enforcement; insufficient or inaccessible incentives.	Clear standards; enforceable regulations; incentives and subsidies; coordinated institutional oversight.
Supply chain & infrastructure systems	Reverse logistics, collection and transportation enable movement of EoL batteries to appropriate pathways.	Collection, transportation and reverse logistics were identified as crucial to implementation.	Insufficient collection infrastructure and inefficient EoL management networks.	Collection networks; reverse-logistics systems; recycling facilities; transportation capacity; industry collaboration.

Source: Author's work

It appears that the five themes represent intertwined rather than separate dimensions of EoL battery management. Indeed, according to existing literature, circular economy strategies like reuse, second-life use, and recycling help to extend the lifecycle of batteries and prevent resource exhaustion [6], [7]. In this study, however, the experts point out that those opportunities require the development of advanced technologies of recycling and resource recovery as well as digital monitoring to evaluate the state of the batteries and choose appropriate EoL options, which is in line with previous studies in this area [1], [3], [9]. Moreover, the findings confirm the role of regulatory policies and infrastructure that has already been em-

phasized in previous studies [3], [10]. Nevertheless, the experts stress the importance of their interconnection since weak infrastructure, regulation gaps, costs, and lack of technology can together prevent the implementation of those strategies.

The five themes discussed in this case are analytical yet very much interconnected instead of being mutually exclusive collectively exhaustive (MECE). The integration of circular economy stands for the overall strategy, while advanced recycling and resource recovery stand for the main value recovery pathways. Digitalization, policies and regulations, and supply chains and infrastructure systems stand for cross-cutting enablers to implement these pathways. In practice, conflicts may be observed between the second-life use and direct recycling, advanced technology and cost efficiency, and policies and operational flexibility. Hence, EoL battery management needs to be done via a combined prioritization process through which the regulation and infrastructure allow the evaluation and routing process with the help of digitalization.

5 CONCLUSION

This study used thematic analysis of expert perceptions to identify strategic pathways for sustainable end-of-life EV battery management. Findings highlight five key dimensions: circular economy adoption, recycling technology, digitalization, policy development, and supply chain infrastructure. While experts recognized second-life use, advanced recycling, and digital tools as essential enablers, persistent barriers, scalability, cost, infrastructure gaps, and regulatory shortfalls continue to limit progress, underscoring the need for an integrated management approach. The findings offer practical guidance for industry managers on combining reuse, recycling, and digital monitoring. Yet there are limitations to this study such as geographical restriction, expert number limitation and time restrictions.

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Service Quality, Satisfaction and Revisit Intention in Ayurveda Resorts in the Western Province in Sri Lanka

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ABSTRACT: Revisit intention is a key indicator of tourist loyalty, and expectation-confirmation theory suggests that service quality shapes revisit intention mainly through tourist satisfaction. However, research on services also shows that service quality can influence behavioural intentions directly, and it is unclear which pathway applies to Ayurveda wellness tourism. This study examines the effects of service quality on satisfaction and revisit intention, and the mediating role of satisfaction among visitors to Ayurveda wellness resorts in Sri Lanka's Western Province. Using a cross-sectional survey of 63 domestic and international tourists, the data were analysed with reliability and validity tests, regression and bootstrapped mediation analysis. Consistent with prior studies, service quality strongly predicted satisfaction ($\beta = .918$, $p < .001$) and revisit intention (total effect $\beta = .787$, $p < .001$). With both predictors entered, service quality retained a significant direct effect ($\beta = .449$, $p = .024$), whereas satisfaction did not ($\beta = .368$, $p = .063$), and the indirect effect was not significant. However, service quality and satisfaction lacked discriminant validity, and the direct-only pattern was sensitive to one influential case. The study extends the service quality–satisfaction–revisit model to Ayurveda wellness tourism, a rarely examined setting, using bootstrapped mediation with validity and robustness checks. It identifies a possible boundary condition of the model: in highly personalised wellness services, evaluations of service quality and satisfaction converge, so mediation should not be assumed. For managers, consistent, high-quality therapeutic service delivery appears to be the main lever for encouraging repeat visits.

Keywords: Ayurveda wellness tourism, revisit intention, service quality, tourist satisfaction, wellness resorts, Western Province of Sri Lanka

1 INTRODUCTION

Understanding why tourists decide to return to a destination continues to be an important topic in tourism research because repeat visitors play a valuable role in maintaining destination competitiveness, lowering marketing costs, and supporting long-term business sustainability [1]. For this reason, revisit intention is widely used as an indicator of tourist loyalty. In many tourism settings, visitors who experience high-quality services are more likely to feel satisfied, and this satisfaction often encourages them to revisit the same destination or tourism provider [2], [3], [4]. However, it is still unclear whether this pattern applies equally across different types of tourism experiences.

Wellness tourism has expanded rapidly in recent years as more travellers look for experiences that improve their physical, mental, and emotional well-being [5]. Sri Lanka has become well known for Ayurveda wellness tourism because of its long history of Ayurvedic healing and holistic treatment practices [6]. Health and Ayurveda visitors

also stay longer than any other visitor group (15.22 versus 8.57 nights on average in early 2025) [7]. Unlike conventional tourism, Ayurveda wellness resorts focus on personalised care, where visitors interact closely with therapists throughout their stay and receive treatments tailored to their individual needs. Yet Sri Lankan studies have mainly treated satisfaction as the direct antecedent of revisit [8], whereas the services literature shows that service quality can also shape behavioural intentions directly [9], [10], [11]. Whether the satisfaction pathway holds where the service itself is the therapeutic product has not been tested.

Accordingly, this study examines the effects of service quality on tourist satisfaction and revisit intention, the effect of satisfaction on revisit intention, and the mediating role of satisfaction among tourists visiting Ayurveda wellness resorts in the Western Province of Sri Lanka, the country's main tourism hub. Methodologically, the study uses bootstrapped mediation analysis with validity and robustness checks rather than the causal-steps approach [12], [13].

2 LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

2.1 *Service quality in tourism and wellness settings*

Service quality is considered one of the main factors influencing tourists' behavioural intentions since it shapes how visitors evaluate the services they receive during their travel experience. The SERVQUAL model explains service quality through five dimensions: assurance, empathy, reliability, responsiveness, and tangibles [14]. Tourism-specific adaptations such as LODGSERV [15] and HOLSERV [16] retain these core dimensions while rewording items for their settings, and SERVPERF showed that performance-only measures predict outcomes at least as well as gap scores [17]. Following this logic, this study adapted performance-based items validated in a tourism setting [4] to Ayurveda services (e.g., staff knowledge of Ayurveda treatments, understanding of guests' health needs, and safety during treatments).

2.2 *Service quality and tourist satisfaction*

According to the Expectation-Confirmation Theory, satisfaction occurs when tourists feel that their experiences meet or exceed what they expected before their visit [18]. As a result, studies have reported that better service quality leads to higher tourist satisfaction [2], [3]. In medical and wellness tourism, satisfaction is formed largely through interaction with practitioners and the quality of treatment [19], [20]. Hence:

H1: Service quality has a significant positive effect on tourist satisfaction.

2.3 *Tourist satisfaction and revisit intention*

Revisit intention refers to a tourist's willingness to return to a destination or tourism service provider after having a positive experience. It is also regarded as an important indicator of destination loyalty and long-term business sustainability [2]. Previous research has identified both service quality and tourist satisfaction as important factors influencing revisit intention, with tourist satisfaction commonly acting as the link between service quality and tourists' future behavioural intentions [3], [8]. Satisfaction has also been reported as a direct predictor of revisit intention among wellness tourists in Sri Lanka [8]. Therefore:

H2: Tourist satisfaction has a significant positive effect on revisit intention.

2.4 *Service quality and revisit intention*

Service quality may also influence behavioural intentions directly. Favourable service quality assessments lead customers to express loyalty [9], and service quality has been found to affect behavioural intentions directly as well as through satisfaction, both across service industries [10] and in tourism [11]. In Ayurveda resorts, where guests follow multi-day treatment programmes, the quality of care itself may be a key reason to return. Thus:

H3: Service quality has a significant positive effect on revisit intention.

2.5 *The mediating role of tourist satisfaction*

Although many previous studies assume that tourist satisfaction explains the relationship between service quality and revisit intention, this assumption has rarely been examined in the context of Ayurveda wellness tourism. Moreover, service quality and satisfaction are closely related evaluations that consumers do not always distinguish [21], so satisfaction may add little beyond service quality where the two overlap. The conventional hypothesis is nevertheless tested:

H4: Tourist satisfaction mediates the relationship between service quality and revisit intention.

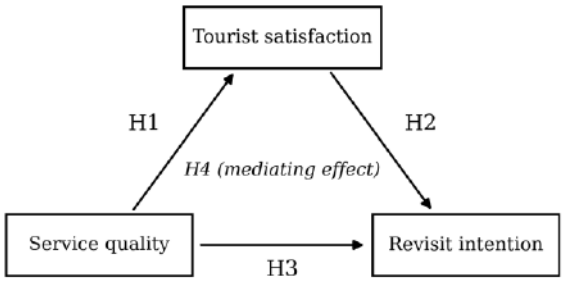


Figure 1. Conceptual framework

3 RESEARCH METHODOLOGY

A quantitative, deductive design grounded in a positivist philosophy was used [22]. Primary data were collected through a cross-sectional survey of tourists who had visited Ayurveda wellness resorts in the Western Province of Sri Lanka. The province was selected because it holds the largest share of rooms registered with the Sri Lanka Tourism Development Authority (19,924 of 56,702 in June 2025) [7], contains the main international airport, and has a coastal belt (Negombo, Wadduwa, Kalutara and Beruwala) with many established Ayurveda resorts serving both domestic and international guests. Focusing on one province also held regional differences in resort type constant, although it limits generalisation.

Convenience sampling was used because a complete sampling frame was unavailable and access to respondents was limited. A total of 63 valid responses were collected. An a priori power analysis in G*Power [23] ($f^2 = 0.15$, $\alpha = .05$, power = .80, two predictors) indicated 68 cases for the overall model and 55 for a single coefficient. The 31.5:1 case-to-predictor ratio exceeds the 15–20:1 recommended by Hair et al. [24] but falls short of Green's [25] 104 + m rule for individual predictors; with N = 63, only effects of $f^2 \geq 0.13$ could be detected with 80% power, which is considered when interpreting the results.

Data were gathered using a structured, self-administered questionnaire. Service quality was measured using 13 items adapted from [4]. Tourist satisfaction (five items) and revisit intention (four items) were measured using the scales of [3] and [26], respectively. All variables were measured on a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

The data were analysed using IBM SPSS Statistics 29. Descriptive statistics were used to summarise the demographic characteristics of the respondents and the study variables [27]. Reliability was assessed with Cronbach's alpha and composite reliability (CR); validity with average variance extracted (AVE), the Fornell–Larcker criterion [28] and the heterotrait–monotrait (HTMT) ratio [29]; and common method bias with Harman's test and full collinearity variance inflation factors (VIFs) [30], [31]. Hypotheses were tested by regression on item-mean scores. The mediating role of tourist satisfaction was assessed with a bootstrapped test of the indirect effect (5,000 resamples; percentile and bias-corrected 95% confidence intervals) following PROCESS Model 4 [13], which, unlike the causal-steps method [32], tests the indirect effect directly without assuming normality [12]. Robustness was checked with HC3 standard errors and Cook's distance.

4 ANALYSIS, FINDINGS, AND DISCUSSION

4.1 *Demographic Profile of Respondents*

Table 1. Demographic profile of respondents (N = 63)

Characteristic	Category: n (%)
Gender	Male 27 (42.9); female 34 (54.0); prefer not to say 2 (3.2)
Age (years)	18–29: 14 (22.2); 30–45: 26 (41.3); 46–61: 14 (22.2); 62+: 9 (14.3)
Nationality	Sri Lankan 25 (39.7); foreign 38 (60.3)
Previous visits	First visit 20 (31.7); once before 21 (33.3); two or more 22 (34.9)
Main purpose	Wellness/relaxation 30 (47.6); medical treatment 11 (17.5); stress relief 10 (15.9); general health 9 (14.3); other 3 (4.8)

A total of 63 valid responses were included in the analysis. The distribution of first-time and repeat visitors was relatively balanced, and most respondents were female, foreign and aged 30–45, visiting mainly for wellness and relaxation (Table 1).

4.2 *Descriptive Statistics, Reliability and Validity*

The descriptive statistics show that respondents generally gave positive ratings for service quality, tourist satisfaction, and revisit intention. All scales were reliable (α = .915–.949; CR = .941–.956; corrected item-total correlations > .60), and AVE exceeded .50 for each construct, supporting convergent validity [28]. The KMO value was .910 and Bartlett's test was significant (χ^2 = 1352.02, df = 231, $p < .001$).

A very strong positive relationship was found between service quality and tourist satisfaction (r = .918, $p < .001$), and both were strongly related to revisit intention (r = .787 and .781). Revisit intention was empirically distinct from the other constructs (AVE = .894; HTMT < .90 [29]), but the service quality–satisfaction correlation exceeded both constructs' AVE, their HTMT was .979, and a principal component analysis of all 22 items extracted two rather than three components, with service quality and satisfaction items loading together. Discriminant validity between these two constructs is therefore not established, consistent with evidence that consumers do not always separate the two judgements [21]. Harman's test (first factor: 63.02% of variance) and full collinearity VIFs above 3.3 for service quality (6.90) and satisfaction (6.71) [31] also indicate possible common method variance [30].

Table 2. Means, standard deviations and reliability of the study variables

Variable	Mean	SD	α	CR	AVE
1. Service Quality	53.38	8.41	.949	.956	.628
2. Tourist Satisfaction	20.60	3.53	.919	.943	.769
3. Revisit Intention	15.87	3.08	.915	.941	.799

Note. N = 63. Means and SDs of summated scales (item means 4.11, 4.12 and 3.97). α = Cronbach's alpha; CR = composite reliability; AVE = average variance extracted.

Table 3. Correlations and discriminant validity

Construct	1	2	3
1. Service quality	(.792)	.979	.847
2. Tourist satisfaction	.918**	(.877)	.851
3. Revisit intention	.787**	.781**	(.894)

Note. Diagonal: √AVE; below diagonal: Pearson correlations (** $p < .001$); above diagonal: HTMT ratios.

4.3 *Hypothesis Testing*

To test the proposed hypotheses, regression analysis was carried out; Table 4 separates the total, direct and indirect effects.

Service quality had a significant positive effect on tourist satisfaction (β = .918, $p < .001$), explaining 84.2% of the variance (R^2 = .842). This result is consistent with previous tourism and hospitality studies [2], [19], although part of the association reflects the overlap between the constructs. Therefore, H1 was supported.

Tourist satisfaction did not have a statistically significant positive effect on revisit intention when service quality was included in the regression model (β = .368, p = .063). On its own, satisfaction strongly predicted revisit intention (β = .781, $p < .001$), so the result reflects the absence of a unique contribution once service quality is controlled (path b), contrary to studies treating satisfaction as a direct predictor [8]. Therefore, H2 was not supported.

The regression analysis also showed that service quality had a significant positive effect on revisit intention (β = .787, $p < .001$), explaining approximately 62.0% of the vari-

ance (R^2 = .620). This is the total effect (c); with satisfaction added, the direct effect (c′) fell to β = .449 but remained significant (p = .024; R^2 = .641). This supports studies reporting direct effects of service quality on loyalty [9], [10]. Therefore, H3 was supported.

The mediating role of tourist satisfaction was examined using a bootstrapped test. The indirect effect was 0.402 (SE = 0.367; completely standardised = .338), but both the percentile (−0.345 to 1.018) and bias-corrected (−0.426 to 0.966) 95% confidence intervals included zero. Based on these results, the mediating role of tourist satisfaction was not supported, and H4 was rejected. This pattern corresponds to direct-only non-mediation [12].

Table 4. Summary of hypothesis testing

Hypothesis	Path	β	p / 95% CI	Result
H1	SQ → TS (a)	.918	< .001	Supported
H2	TS → RI, controlling for SQ (b)	.368	.063	Not supported
H3	SQ → RI, total effect (c)	.787	< .001	Supported
	SQ → RI, direct effect (c′)	.449	.024	–
H4	SQ → TS → RI, indirect (a × b)	.338[a]	−0.345 to 1.018[b]	Not supported

Note. β = standardised coefficient; SQ = service quality; TS = tourist satisfaction; RI = revisit intention. [a] Completely standardised indirect effect. [b] Percentile bootstrap 95% CI of the unstandardised indirect effect (0.402), 5,000 resamples.

4.4 *Robustness Checks and Discussion*

Two checks qualify these results. With HC3 standard errors (residuals were non-normal, Shapiro–Wilk p < .001), neither the direct effect (p = .215) nor satisfaction (p = .347) was individually significant, although the predictors were jointly significant (F(2, 60) = 56.26, p < .001). One respondent, a first-time international visitor with maximum satisfaction but low revisit intention, had a Cook's distance of 1.23 (all others < 0.10). Without this case, the direct effect became non-significant (β = .144, p = .390), satisfaction became significant (β = .740, p < .001) and the indirect effect was significant (0.780, 95% CI 0.434 to 1.094), indicating full mediation. The case was retained, as there was no evidence of a data error.

The findings therefore support H1 and H3: service quality is a strong and robust predictor of satisfaction and revisit intention, consistent with direct-effect arguments [10], [11]. The rejection of H4 is better read as an absence of evidence for mediation than as evidence against it, for four reasons: service quality and satisfaction were not empirically distinct (HTMT = .979); collinearity (VIF = 6.33) inflated the standard errors; the unique effect of satisfaction was small (f^2 = 0.06) and the test had only about .48 power to detect it; and the direct-only pattern depended on one case. Substantively, in Ayurveda resorts the service is the core product and guests spend long periods with physicians and therapists, so satisfaction appears to be largely a judgement of the care received rather than a separate intervening step. Where the two evaluations converge, the paths of the conventional mediation model may not be empirically separable, suggesting a boundary condition for the model.

5 CONCLUSION

The results showed that service quality had a significant positive effect on both tourist satisfaction and revisit intention. However, tourist satisfaction did not have a significant positive effect on revisit intention once service quality was considered, and its mediating role was not supported by the bootstrapped test. Because the two constructs overlapped strongly and the direct-only pattern was not robust, the safest conclusion is that service quality robustly predicts revisit intention while the route through which it operates remains uncertain; the conventional mediation model should therefore not simply be assumed in highly personalised wellness settings.

The findings also have practical value for Ayurveda wellness resort managers. Maintaining consistently high service standards, investing in well-trained staff, and providing high-quality therapeutic experiences are likely to encourage repeat visits and strengthen customer loyalty. Managers should treat service delivery itself as the main lever for repeat visits by employing qualified physicians and certified therapists, tailoring and explaining treatment plans, delivering promised services reliably, monitor-

ing specific service attributes rather than generic satisfaction scores, and keeping in contact with international guests after their stay. The Sri Lanka Tourism Development Authority and the Department of Ayurveda could reinforce this through service standards and practitioner accreditation. From an academic perspective, the study provides further evidence that the role of tourist satisfaction may vary depending on the tourism context, and shows the importance of testing discriminant validity and robustness before interpreting mediation results.

Like any research, this study has several limitations. The relatively small sample size (n = 63) may reduce the generalisability of the findings. In addition, convenience sampling limits how well the sample represents the wider tourist population. The cross-sectional, single-source design leaves common method variance possible, discriminant validity between service quality and satisfaction was not established, and the service quality scale was not wellness-specific.

Future studies could build on these findings by collecting data from larger and more diverse samples across different wellness tourism destinations, using wellness-specific measures and time-lagged or multi-source data such as actual repeat bookings. Applying analytical techniques such as structural equation modelling would provide a more comprehensive assessment of the indirect relationships among the study variables.

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Composite Indicator for Measuring Students' Responsible AI adaptation Behaviour Across Ethical, Technological, and Institutional Dimensions

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ABSTRACT: Generative Artificial Intelligence (GenAI) tools are increasingly being used by university students for different academic activities, including learning, communication, and problem solving. Existing models, such as the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT), have contributed to understanding technology adoption. Nevertheless, they offer limited insight into whether students engage with AI tools ethically, transparently, and responsibly. To address this gap, this study presents a Responsible Explainable AI (Responsible-XAI) framework for examining responsible AI usage among higher education students. Survey data from 729 students at a Sri Lankan higher education institution were used to examine five dimensions: Transparency and Explainability, Ethical Awareness, Data Privacy and Governance, Performance Expectancy, and Institutional Trust. These dimensions were combined to develop a Responsible AI Behaviour Index (RABI), which classified students into three levels of responsible AI adherence: Low, Moderate, and Active. Six baseline machine learning models were evaluated for predicting these levels. Logistic Regression achieved the highest performance, with an accuracy of 95.2% and a Macro-F1 score of 0.938. SHapley Additive exPlanations (SHAP), Local Interpretable Model-Agnostic Explanations (LIME), and counterfactual explanations were then used to examine the factors associated with the predicted responsible AI behaviour. The results show that explainability awareness, ethical understanding, and institutional trust had stronger associations with responsible AI usage, while privacy awareness had a comparatively lower contribution to distinguishing the different levels of adherence. The study therefore brings together technology acceptance factors with ethical, explainability, privacy, and institutional considerations to examine responsible AI usage in higher education.

Keywords: AI Adaptation, AI Governance, Higher Education, Responsible Artificial Intelligence, XAI

1 INTRODUCTION

Generative AI has become increasingly visible in university education. Students now use these tools for searching for information, writing, coding, and other study-related activities. As this use becomes more common, universities also need to consider how students are using AI, not only whether they are using it. Although research on AI adoption in higher education has increased in recent years [1], [3] less attention has been given to the responsible use of these tools. This is important because students may use AI-generated content without fully understanding its limitations. The outputs may contain inaccurate, biased, or misleading information, and relying on them without proper checking can create problems related to academic integrity, including undisclosed AI use, plagiarism, and the use of hallucinated content in assessed work [3], [5].

Responsible Artificial Intelligence (RAI) has therefore become an important area of

discussion in education. RAI focuses on issues such as transparency, fairness, accountability, privacy, and appropriate human oversight [4], [6]. In the context of students, responsible use also involves checking AI-generated information, recognising the limitations of AI systems, maintaining academic integrity, and using AI as support for learning rather than as a replacement for it [5], [7]. These aspects are not fully captured when AI use is considered only from the perspective of technology acceptance.

Many studies have examined students' usage of AI using established technology adoption models such as the TAM and the UTAUT [8], [9]. These studies commonly consider factors such as usefulness, ease of use, social influence, and facilitating conditions. However, accepting and using an AI tool does not necessarily mean that it is being used responsibly. TAM and UTAUT were mainly developed to explain technology acceptance and use, and therefore do not fully address concerns such as ethical awareness, transparency, privacy, trust, or the need to question AI-generated outputs [3], [4]. Similar work using UTAUT, TAM, DOI, and SEM has also mainly examined students' intention to use AI and their actual usage [10]-[12]. This leaves an important difference between using AI and using AI responsibly. A student may use AI regularly, for example, while still accepting its answers without checking their accuracy, considering privacy concerns, or recognizing possible bias.

Another issue arises when machine learning is used to study such behaviour. Predictive models can identify patterns in data, but some models provide limited information about why a particular prediction is made. This becomes important when the purpose of the analysis is to understand the factors related to human behaviour. Explainable AI (XAI) can help address this issue by providing information about the contribution of individual factors to model predictions. Methods such as SHapley Additive exPlanations (SHAP) and Local Interpretable Model-Agnostic Explanations (LIME) can therefore be used to examine these contributions and provide more interpretable results [6], [7].

In this study, we develop a Responsible AI Behaviour Index (RABI) to examine responsible AI use among higher education students. The index brings together five dimensions: Transparency and Explainability, Ethical Awareness, Data Privacy and Governance, Performance Expectancy, and Institutional Trust. Rather than looking at technology acceptance alone, RABI considers behavioural, ethical, technological, and institutional aspects of students' AI use. The study also evaluates six machine learning classification models and uses SHAP, LIME, and counterfactual explanations to examine the factors associated with responsible AI behaviour.

The study makes three main contributions. First, it introduces RABI as a composite measure of responsible AI use across the five dimensions. Second, it combines machine learning with global, local, and counterfactual explainability methods to examine the factors associated with responsible AI behaviour and individual model predictions. Third, it provides evidence from 729 students in a Sri Lankan higher education institution, contributing to the relatively limited research on responsible AI use in developing-country educational contexts.

Accordingly, the study has three objectives: (i) to develop a composite Responsible AI Behaviour Index (RABI) across five constructs; (ii) to apply SHAP, LIME, and counterfactual analysis to identify the constructs most associated with responsible AI behaviour; and (iii) to provide empirical evidence from a Sri Lankan higher education context.

The remainder of the paper is organized as follows. Section 2 reviews the existing literature and identifies the research gap. Section 3 presents the proposed framework and the methodology followed in the study. The results are presented and discussed in Section 4, followed by the conclusion in Section 5.

2 LITERATURE REVIEW

Previous studies have mainly looked at AI use in higher education from the technology acceptance perspective. Factors such as perceived usefulness, ease of use, social influence, and institutional readiness have been linked to students' willingness to use AI [2], [8], [9]. TAM has been frequently applied to this area, particularly to examine how perceived usefulness and perceived ease of use affect technology acceptance [11], [12]. UTAUT extended this perspective by considering performance expectancy, effort ex-

pectancy, social influence, and facilitating conditions [10]. Later, UTAUT2 included additional factors such as habit, hedonic motivation, and perceived value, which have also been examined in relation to students' use of Generative AI [10], [13], [14]. These studies show that students' decisions to use AI are influenced by both their perceptions of the technology and the environment in which they use it. In practice, students use AI for tasks such as searching, summarising, coding, and learning, and their use can also be influenced by peers, lecturers, and institutional recommendations [11], [15].

These models are useful for understanding why students accept and use AI, but they do not fully explain what happens after adoption. Using an AI tool does not necessarily mean that the tool is being used carefully or responsibly. This distinction is important in education because students may accept AI-generated information without checking its accuracy, considering privacy issues, or recognising possible bias.

Responsible AI research considers some of these issues from an ethical and governance perspective. A review of global AI ethics guidelines found common principles related to transparency, justice and fairness, non-maleficence, responsibility, and privacy [16]. The AI4People framework proposed by [17] similarly identified beneficence, non-maleficence, autonomy, justice, and explicability as important principles for AI. These principles are relevant to higher education because responsible AI use depends not only on whether students are willing to use AI, but also on whether they understand its limitations and use it with appropriate judgement.

Several factors have been linked to responsible AI use, including AI literacy, ethical awareness, trust, and perceived risk [4], [5]. Students need sufficient understanding of AI systems to question and verify the information they produce. This is particularly important when AI systems provide outputs without making their limitations clear. Trust is also important, as students are more likely to rely on systems that they perceive as accurate and reliable, while a lack of transparency can reduce confidence in AI-based decisions [4], [6]. At the same time, excessive trust may encourage students to accept AI outputs without sufficient checking [6], [7].

AI literacy and ethical awareness are also closely related to how students use these tools. Students who understand the limitations of AI are more likely to verify outputs, consider the handling of personal information, and follow institutional requirements [3], [5]. Ethical awareness is particularly relevant to academic integrity, including the honest disclosure of AI assistance and appropriate use of AI-generated content [4]. Privacy, inaccurate information, algorithmic bias, and over-reliance on automated systems remain important concerns in this area [3], [17]. The university environment can further influence these behaviours through peer interaction, personal experience, institutional policies, and guidance from lecturers [11], [15]. Clear guidelines and awareness programmes can help students understand how AI should be used, while limited guidance can leave students uncertain about appropriate practices [18], [19].

Another issue concerns how responsible AI behaviour can be studied using machine learning. Machine learning models can identify patterns and relationships in student data, but some models provide little information about why a particular prediction is made. Explainable AI (XAI) can help make these predictions easier to interpret. Techniques such as SHAP and LIME can be used to examine the contribution of individual variables to model predictions [3], [4]. This is useful in the present study because identifying which factors are associated with responsible AI behaviour is as important as obtaining a reliable classification.

Based on the literature reviewed, the five dimensions used in the Responsible AI Behaviour Index (RABI) were selected to represent three related areas of responsible AI use. Transparency and Explainability and Performance Expectancy represent the technological aspects, Ethical Awareness and Data Privacy and Governance represent the ethical aspects, and Institutional Trust represents the institutional aspect. These dimensions appear across the literature, but they are generally examined separately rather than as part of a single measure of students' responsible AI behaviour.

Several gaps can therefore be identified. Much of the existing research examines students' intention to use AI, acceptance, readiness, or general usage rather than how they use AI after adoption. In addition, commonly used statistical approaches such as regression and structural equation modelling are

useful for examining relationships between variables, but they provide less information about individual predictions and the relative contribution of different factors in a classification problem. There is also limited work that brings technology acceptance factors together with responsible AI concerns such as transparency, ethical awareness, privacy, and institutional trust. This gap is particularly relevant in contexts such as Sri Lanka, where evidence on responsible AI use among higher education students remains limited.

3 METHODOLOGY

This study used a quantitative research approach to examine factors influencing Responsible AI adoption and develop an explainable machine learning framework for classifying responsible AI behaviour.

Figure 1 presents the overall Responsible-XAI framework proposed in this study.

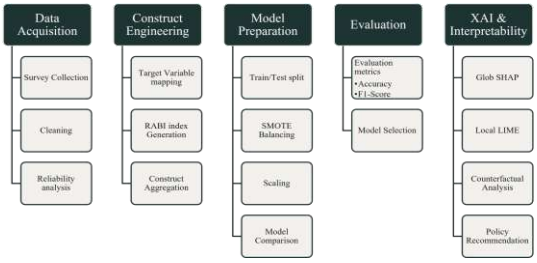


Figure 1. Responsible XAI framework

3.1 *Data Acquisition*

Data were collected from 729 valid survey responses using a structured questionnaire with a five-point Likert scale, distributed to undergraduate students at NSBM Green University via online method between October - November 2025 using random sampling. Before analysis, the dataset was cleaned by removing incomplete and straight-line responses.

Missing values (less than 5%) were imputed using the median for numerical variables and the mode for categorical variables. The data were then standardized, anonymized, and prepared for further analysis. This study did not collect any personal identifiable or sensitive information.

Participation was entirely voluntary, and students completed the anonymous survey after being informed of the purpose of the study; no formal ethics committee approval was required under the institution's guidelines for anonymous, non-sensitive academic surveys.

3.2 *Construct Engineering*

Five key constructs were considered in the study: Transparency and Explainability, Ethical Awareness, Data Privacy and Governance, Performance Expectancy, and Institutional Trust. The multi-item constructs were calculated by averaging their corresponding questionnaire items, while Data Privacy and Governance was measured using a single survey item. The reliability of the constructs was evaluated using Cronbach's alpha, indicating acceptable to good internal consistency overall, though Performance Expectancy and Institutional Trust ($\alpha = 0.677$) sit at the lower acceptable bound and should be interpreted with some caution. Construct validity was assessed using Spearman's rank correlation, confirming that the constructs were related while measuring different aspects of responsible AI adoption. Because Data Privacy and Governance used a single item, its reliability could not be assessed via Cronbach's alpha, a limitation addressed in future multi-item designs. An overall Responsible AI Behaviour Index (RABI) was then calculated by combining the five constructs with equal importance and scaling the result to a score between 0 and 100. where $K = 5$ represents the number of constructs and x_c represents the construct score. Equal weighting was used in the absence of prior evidence. favouring any single dimension; alternative weighting schemes are left for future work.

$$RABI = \left(\frac{\frac{1}{K}\sum_{c=1}^{K} x_c - 1}{4}\right) X\ 100 \qquad (1)$$

3.3 *Model Preparation*

Participants were subsequently classified into three RABI categories: Low, Moderate, and Active. The thresholds were determined using the original five-point Likert scale and the empirical score distribution. A RABI score of 50 corresponds to the neutral Likert midpoint of 3.0; therefore, a lower threshold of 45 was used to ensure that the Low category represented scores below neutral. A score of 45 corresponds to a Likert-equivalent mean of 2.80 and lies approximately 0.92 standard deviations below the

sample mean (μ = 58.91, σ = 15.05), closely approximating the μ − 1σ boundary of 43.86. The threshold was rounded to 45 for practical interpretability. The upper threshold of 70 was based on the third quartile (Q3 = 69.39), rounded to 70. Accordingly, scores <45, 45–<70, and ≥70 were classified as Low, Moderate, and Active, respectively.

The resulting RABI categories were then used as the target variable for machine learning classification. The dataset was split into training (80%) and testing (20%) sets using stratified sampling. SMOTE was applied to the training set only to address class imbalance, followed by feature standardization. Six machine learning algorithms-Logistic Regression, Support Vector Machine (SVM), Decision Tree, Random Forest, XGBoost, and LightGBM—were trained and compared using five-fold stratified cross-validation.

3.4 *Evaluation*

The performance of the models was evaluated using accuracy, precision, recall, and macro F1-score. Five-fold stratified cross-validation was used to validate the performance of the machine learning models and assess their consistency across different subsets of the training data.

3.5 *XAI and Intepretability*

To improve the transparency of the classification process, SHAP was used to explain overall feature importance, LIME was applied to interpret individual predictions, and counterfactual explanations were generated to identify the smallest changes required for a participant to move from one behavioural category to another. Together, these methods provided both global and individual-level explanations of the model, helping to identify the main factors associated with responsible AI behaviour and how changes in these factors may influence the predicted behavioural category.

Table 1. Reliability analysis of constructs

Construct	Score Formula	Cronbach's α
Transparency and Explainability	$EXAI = \frac{1}{4}\sum_{i=1}^{4} x_i$	0.817
Ethical Awareness	$Ethical = \frac{1}{7}\sum e_i$	0.816
Performance Expectancy	$Perf = \frac{1}{5}\sum p_i$	0.677
Institutional Trust	$Trust = \frac{1}{4}\sum t_i$	0.677
Privacy Awareness	Single item	Single item

4 RESULTS AND DISCUSSION

RABI scores (mean = 58.91, SD = 15.05) classified students as Low (<45), Moderate (45–70), or Active (>70) adherents. Most students (63.1%) fell into the Moderate category, 13% were Low Adherents requiring intervention, and 23.9% showed Active, proactive responsible AI engagement. The distribution of the calculated RABI scores together with the classification boundaries is illustrated in Figure 2.

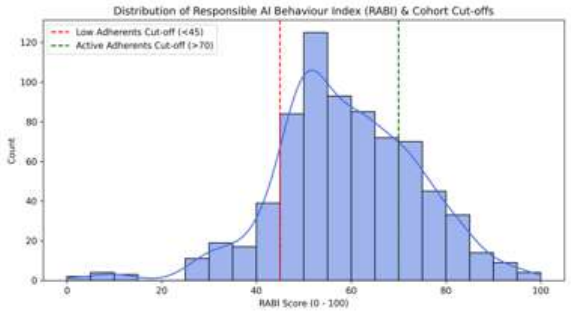


Figure 2. Distribution of the calculated RABI scores

As given in Table 2, of six classifiers tested, Logistic Regression generalized best on holdout data (Macro F1 = 0.9383) and was selected. The model achieved 95.2 percent accuracy (Macro F1 = 0.94), with perfect recall for Active Adherents and an F1-score of 0.89 for Low Adherents.

Table 2. Comparison of classification model performance

Classifier	Mean CV Macro F1	Test Macro F1
Logistic Regression	0.9799	0.9383
SVM (RBF Kernel)	0.9845	0.9259
Random Forest	0.9764	0.9288
LightGBM	0.9700	0.9127
XGBoost	0.9773	0.8791
Decision Tree	0.9259	0.8296

To identify underlying behavioural drivers beyond classification, a three-level explainability framework (global, local, and counterfactual) was applied. Global feature contributions were analysed using SHAP's Linear Explainer for the selected Logistic Regression model. Figure 3 presents the SHAP beeswarm plots for the three behavioural profiles, illustrating the relative importance and direction of each Responsible AI construct. LIME analysis in Figure 4 showed low XAI and Privacy scores drove Low Adherent predictions; balanced contributions marked Moderate Adherents, while strong XAI, Institutional Trust, and Ethical Awareness scores characterized Active Adherents.

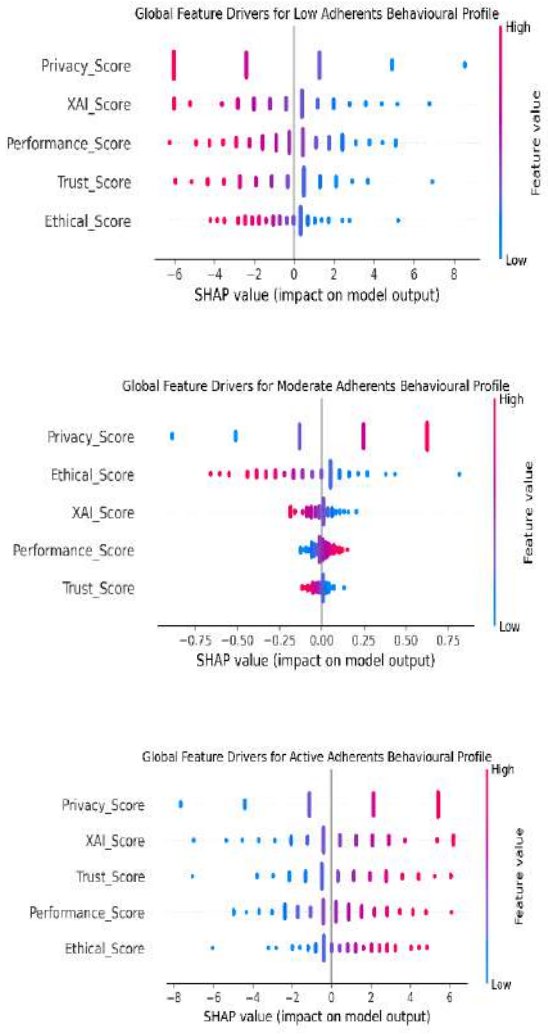


Figure 3. SHAP beeswarm plot

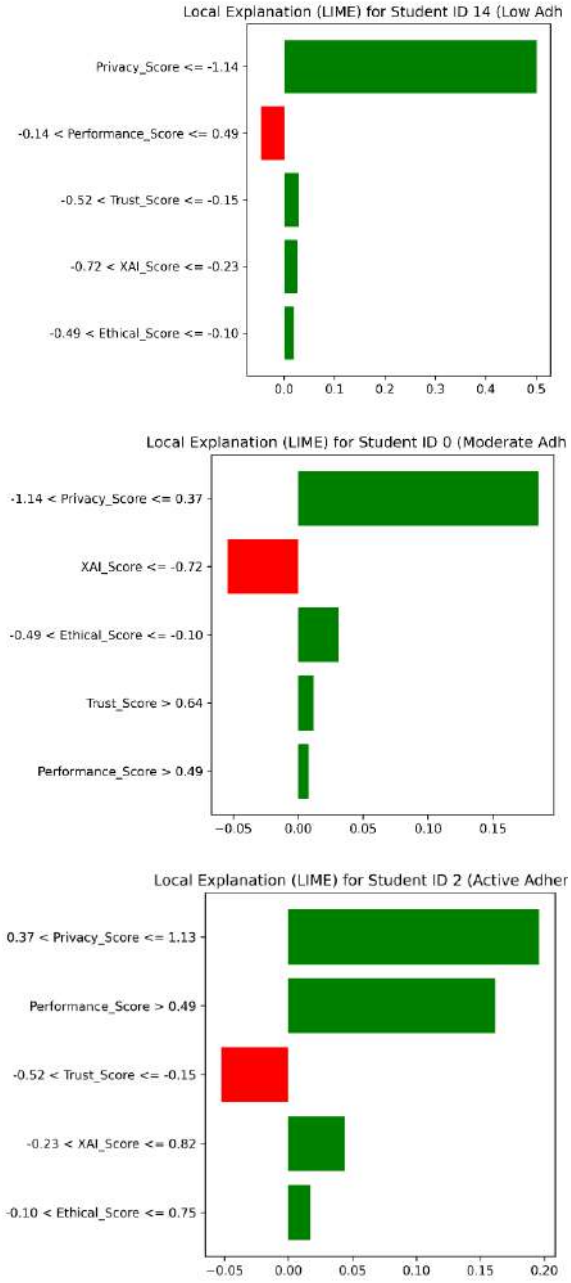


Figure 4. LIME-based local explanation of the responsible AI behaviour prediction

Counterfactual analysis on a representative Low Adherent student showed that raising all five construct scores by roughly 1.50 points reclassified the student as Active Adherent with 99.99 percent confidence. This illustrates which constructs the model relies on most heavily to distinguish behavioural categories, but it should not be interpreted as evidence that increasing these scores will causally produce more responsible AI use, since the underlying analysis is observational and the outcome categories are derived from the same constructs. Table 3 presents an example counterfactual explanation for a selected student classified under the Low

Adherence category, showing the feature changes required to move towards a higher responsible AI behaviour category.

Note that RABI, used to define the Low/Moderate/Active labels, is built from the same five constructs used as predictors; the resulting high classification accuracy therefore reflects this internal relationship rather than independent out-of-sample predictive validity. This does not undermine the exploratory explainability findings but should temper claims of strong predictive performance.

5 CONCLUSION

This study proposed a Responsible-XAI framework to identify the key factors associated with responsible AI adoption among 729 higher education students. Among the evaluated machine learning models, Logistic Regression achieved the best performance while remaining interpretable. Explainable AI techniques showed that transparency and explainability awareness, institutional trust, and ethical awareness were the strongest factors associated with responsible AI behaviour. In addition, local and counterfactual explanations provided practical insights into how improvements in these areas are associated with, and may plausibly support, more responsible AI use among students; confirming this would require longitudinal or interventional research. These findings suggest several practical directions: universities and policymakers should embed AI-literacy and ethics modules into curricula and institutional guidelines; lecturers should model and discuss responsible AI use within coursework; and future researchers should test these associations using longitudinal or experimental designs across multiple institutions. Although based on one Sri Lankan institution, the framework offers a foundation for future research validating it across other universities and countries and tracking how students' responsible AI behaviour changes over time.

6 CODE AND DATA AVAILABILITY

The source code, implementation details, and supporting materials are publicly available in the GitHub repository: https://github.com/tcbak/XAI_ResponsibleAI. Raw survey data is withheld for privacy reasons; processed data and full implementation are publicly available.

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Factors Influencing on the Choice of Accounting & Finance Students' Career Pathways: A Case Study of a Private University in Sri Lanka

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ABSTRACT: This study investigates the factors that shape the career pathway choices of accounting and finance undergraduates, a question that has taken on renewed importance as artificial intelligence (AI) reshapes entry-level accounting work. Drawing on Social Cognitive Career Theory, the study examines how intrinsic motivation, extrinsic motivation, third-party influence, and career exposure affect students' career path choices. Data were collected through a self-administered online questionnaire from students enrolled in the accounting and finance degree program at a private university in Sri Lanka. By distributing an online questionnaire, data was collected from a sample of 201undergraduates and and analyzed using multiple regression analysis, following reliability, normality, and multicollinearity diagnostics. The results show that intrinsic motivation ($\beta = 0.457$, $p < 0.001$) and career exposure ($\beta = 0.265$, $p < 0.001$) are significant predictors of career path choice, together explaining 43.7% of the variance in the outcome ($R^2 = 0.437$), whereas third-party influence and extrinsic motivation are not statistically significant. These findings suggest that accounting students' career decisions are driven primarily by personal fulfilment and hands-on exposure to the profession rather than by external reward or social pressure, a pattern that carries added weight as AI redefines the day-to-day content of accounting roles. The study contributes to the literature by extending the SCCT framework with career exposure as an additional determinant and by re-examining established motivational factors within an emerging, technology-disrupted labor market. The findings offer accounting educators, career counselors, and professional accounting bodies in Sri Lanka and comparable contexts evidence-based guidance for designing curricula, mentorship programs, and recruitment strategies that align with what actually drives students' career decisions

Keywords: career path choice, intrinsic and extrinsic motivators, career exposure, third-party influence, Social Cognitive Career Theory

1 INTRODUCTION

One of the most important aspects of a person's life is choosing a career [1]. A person's profession can influence their personality, determine their social standing, and forecast their income. A person's long-term well-being, income, work style, and personality are all greatly impacted by individual's decision on their profession [2]. Not only the person's future but also the economic well-being of whole country can be greatly impacted by a single poor career choice. Such misfits in the workplace will lead to reduce the productivity and efficiency in the whole organization. Every person must eventually deal with the obstacle of the career choice problem [3]. Especially, students face a variety of challenges when choosing a career [4]. It wouldn't be incorrect to say that the choice of study programs is also greatly influenced by the choice of future employment since the individuals must have specialized educational background prior to

embarking on the practical life [5]. Therefore, students are more likely to run across this issue when choosing their study plans. The accounting profession plays a pivotal role in the economic development and financial integrity of nations. Understanding the factors that influence career choices is essential, as they can significantly shape students' preferences and readiness to enter various accounting fields.

This study focuses on students who are enrolled in accounting and finance degree programs. Nowadays, Artificial intelligence (AI) technology is disrupting the conventional role of the accounting profession and requiring rapid paradigm shifts, its widespread application in the modern world presents a substantial challenge for accounting students. These difficulties have led to a decline in the demand for accounting and finance jobs in the labor market. While CIMA only registered 5,527 new members in 2013, ACCA recorded 10,361 new member enrolments despite this declining demand. This implies that more students are pursuing professions in accounting and finance by enrolling in study programs linked to accounting. However, they may decide against pursuing a profession in accounting and finance.

Despite the urgent need to address these issues, there is a noticeable lack of research that thoroughly examines the factors determining accounting and finance students' career path choices, especially considering AI's revolutionary potential. Emerging evidence confirms that AI is already reshaping the career prospects of accounting students and the technical and digital skills that employers expect of them [6], yet this literature has not been connected to the established motivational and social determinants of career choice. The present study addresses this gap by re-examining intrinsic motivation, extrinsic motivation, third-party influence, and career exposure specifically within this AI-disrupted context, rather than simply replicating earlier, pre-AI determinant models. Some studies claim that a variety of factors, including external and internal (or both) influences, significantly affect people's employment choices [7]. Personal interests, personality, and goals are examples of intrinsic motivations, whereas external incentives and employment market trends are examples of extrinsic motivations.

Third-party influence, such as that of friends, family, and teachers, is also required when making a professional decision. Career exposure is particularly important since internships and real-world experiences have a big impact on how students view various career paths [7]. Given this, the main goal of this research is to determine and examine the variables that affect the job choices made by accounting graduates.

Accordingly, research questions can be formulated as follows;

- What is the impact of intrinsic motivational factors on the career choice of accounting and finance students.
- What is the impact of extrinsic motivational factors on the career choice of accounting and finance students.
- What is the impact of the influence of third party on the career choice of accounting and finance students.
- What is the impact of career exposure on the career choice of accounting and finance students.

This research adopts frameworks called Social Cognitive Career Theory to study the student’s career choice. The SCCT is the process by which a person develops his or her job choices, vocational interests, and perseverance [8]. According to SCCT, a person's self-efficacy beliefs and job expectations have an impact on their professional choices and objectives. The study provides a thorough model of career decision-making among accounting and finance students by methodically integrating several factors, including social context, career exposure, extrinsic rewards (financial rewards and job opportunities) and intrinsic motivation (personal interests and values).

According to Jusoff [9], a career path is a lifelong journey that ought to be planned at the start of one's profession. However, according to Joseph et al., a career path is an occupation that a person holds for the whole of their life [14]. In place of advancement in terms of career, personal development, job status, and job satisfaction, “career path” can also refer to work experience [9], [10]. One could use the terms “career path” and “career choice” interchangeably. Based on the definitions provided, the term “career path” in this study refers to the choice of career an accounting student makes after graduating. A student of accounting may choose to pursue a profession in audit, taxation, management accounting, financial accounting, finance, etc. Accounting students often pursue careers in auditing and taxation [11].

Factors that contribute to intrinsic motivation: An activity or object that makes one feel good about themselves is considered intrinsic motivation [12]. He went on to say that a person has intrinsic drive when he does because it challenges or interests him. Conversely, other research described intrinsic drive as a sense of fulfilment that comes from pursuing and looking for an activity [13]. Personal interest and choice are the two elements that make up intrinsic motivation. An individual's personal characteristics may also have an impact on their work route [14]. Past studies have discovered that for accounting students, intrinsic motivation was a crucial component [15]. Results showed that students' career pathways can be positively impacted by intrinsic desire. Another prior research clarified that students' perceptions and sentiments about the accounting profession have a positive and substantial impact on their choice of career [16]. A career in accounting and finance can be intrinsically motivating for students who are confident in their ability to achieve good outcomes and who excel with numbers and figures. However, personality traits such as aptitude and attitude have been found to be important in determining the development of job interest [17].

Extrinsic motivational elements: According to [12], an individual may be inspired to carry out specific actions by external sources. Extrinsic motivation, according to [18], is a driving force that originates from outside of a person. He clarified that even if someone does not enjoy their profession, they may be doing it in order to get anticipated benefits. According to a study by [19], financial accounting could give them greater extrinsic motivation in the form of better advantages and higher compensation. In addition, other earlier research has shown a positive correlation between career route and extrinsic motivation [13], [19], [20]. According to these previous investigations, pay and employment possibilities are the most prominent extrinsic motivation elements that have been discovered to affect career pathways.

Social influence: Career choice can also be affected by a person or a group of people which includes family members, friends, career guidance teachers, and career counselors. According to a number of prior studies, one of the key elements influencing accounting students' job choices is the influence of third parties. These earlier research indicate that parents, subject teachers, family members, and friends all have an impact on students [22]–[24].

Career exposure: The term used in this study describes how youngsters are exposed to information about careers. Most accounting students are exposed to the workforce through professional accounting organizations highlighted that it's critical that students learn about the nature of accounting and the range of employment options available [25]. One can choose a career more wisely if they are exposed to more information about careers. According to earlier research, students' job choices have been impacted by the career exposure provided by professionals [25], [26]. Over half of the students had gained exposure of some kind while attending college [25]. Lecturers, professional accounting organizations' career keynote addresses, and counseling sessions were the sources of exposure.

2 MATERIALS AND METHODOLOGY

2.1 *Materials*

As shown in Figure 1, the following conceptual framework illustrates how the independent factors that were chosen affected the dependent variable.

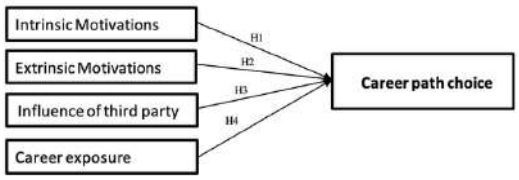


Figure 1. Conceptual framework showing the hypothesized relationships between intrinsic motivation, extrinsic motivation, third-party influence, career exposure, and career path choice

H1: There is a significant positive relationship between intrinsic motivation and Career path choice
H2: There is a significant positive relationship between extrinsic motivation and Career path choice
H3: There is a significant positive relationship between influence of third party and Career path choice
H4: There is a significant positive relationship between career exposure and Career path choice

Measurement: This study operationalized five variables: career path choice, intrinsic motivation, extrinsic motivation, influence of third parties, and career exposure using multi-item scales adapted from prior literature, measured on a five-point Likert scale ranging from "strongly disagree" to "strongly agree." Career path choice, the dependent variable, was measured using five items adapted from [9]. Intrinsic motivation was assessed with five items adapted and extrinsic motivation was also measured using five items from [15]. Influence of third parties was captured through five items adapted from, [26]. Finally, career exposure was measured using four items adapted from [40]. All items were adapted to fit the context of accounting students and were reviewed for content validity prior to data collection.

Although intrinsic motivation, extrinsic motivation, third-party influence, and career exposure are all recognized in the literature as antecedents of career choice, they are conceptually distinct constructs rather than restatements of one another. Intrinsic and extrinsic motivation are differentiated by their locus of causality: the former originates from internal satisfaction, interest, and self-efficacy, whereas the latter stems from external rewards such as pay and job security, and the two are treated as separate constructs in motivation theory [13]. Third-party influence and career exposure, in turn, capture social and experiential channels of influence rather than motivational states, operating through different mechanisms, guidance from significant others versus direct, first-hand exposure to the profession. Each construct was measured with its own validated multi-item scale adapted from prior studies, and the diagnostic tests reported in Section 3.2 confirm that the four variables are empirically distinct: all four recorded Tolerance values above 0.10 and VIF values below 10 (Table 3), indicating no problematic overlap among the predictors and supporting their retention as separate variables in the regression model.

2.2 *Methodology*

This study follows positivistic approach since several relationships are going to be quantified in a systematic manner assuming the objective reality about career choice decision. Study adopted deductive approach since the hypothesis are formulated based on an existing theory and the past literature. The target population in this study is all the students specializing in the field of accounting and finance in the selected private university, Sri Lanka. There are 5600 students attached to the faculty of business in that private university. The accounting and finance student population likely represents a significant portion, potentially 2,000 students across levels and 500 students in the 4th year. Sample size was determined using the Solvin formula, and accordingly the sample size determined was 222. Questionnaires were distributed online to all 222 students in the calculated sample who were pursuing the BM (Hons) in Accounting and Finance degree; of these, 201 valid responses were received and retained for analysis, representing a response rate of approximately 90.5%. The sampling method used in this study is convenience sampling. Participation was voluntary: respondents were informed of the purpose of the study and assured that their responses would remain anonymous and be used solely for academic purposes before giving their consent to complete the questionnaire, in line with standard ethical procedures for research involving human participants.

3 RESULTS AND DISCUSSION

3.1 *Reliability Analysis*

Table 1. Reliability analysis

Construct	Abbrev.	Items	Cronbach's Alpha
Intrinsic Motivation	IM	6	.965
Extrinsic Motivation	EM	6	.946
Third-Party Influence	TPI	5	.824
Career Exposure	CE	5	.725
Career Path Choice	CPC	6	.916

Note. IM = Intrinsic Motivation; EM = Extrinsic Motivation; TPI = Third-Party Influence; CE = Career Exposure; CPC = Career Path Choice.

As shown in Table 1, by evaluating the internal consistency of these constructs through Cronbach's alpha, we can conclude that the items of each variable are closely related and effectively measure the intended concepts.

3.2 *Diagnostic Tests*

Table 2. Normality test

Statistic	IM	EM	TPI	CE	CPC
Skewness	0.245	0.387	0.118	0.294	0.356
Kurtosis	-0.77	-1.03	-0.55	-0.63	-1.070

As shown in Table 2, the normality of the data was examined using skewness and kurtosis statistics. Studies suggest a broader acceptance range, where data can be considered normally distributed if skewness lies between −2 and +2 and kurtosis between −7 and +7 [22], [28]. As shown in Table 2, all variables have skewness values ranging from 0.118 to 0.387, and kurtosis values ranging from −1.07 to −0.55. Since all values fall comfortably within the acceptable range, it can be concluded that the data distributions are approximately normal.

Table 3. Multicollinearity test

Independent Variable	Tolerance	VIF	Decision
Intrinsic motivation	.813	1.230	No multicollinearity
Extrinsic motivation	.671	1.490	No multicollinearity
Third-party influence	.691	1.446	No multicollinearity
Career exposure	.646	1.547	No multicollinearity

All four independent variables show Tolerance values well above .10 and VIF values well below 10. This confirms no multicollinearity issue among the predictors, so all four variables can be reliably retained in the regression model.

3.3 *Regression Analysis*

Table 4. Regression analysis

Predictor	B	SE	Std. β	t	Sig.
(Constant)	1.0075	0.2005	—	5.02	0.0001
Intrinsic motivation	0.4030	0.0445	0.4569	9.06	0.0001
Extrinsic motivation	0.1045	0.0601	0.1021	1.74	0.0831
Third-party influence	-0.0611	0.0455	-0.0647	-1.34	0.1804
Career exposure	0.2997	0.0630	0.2648	4.75	0.0001

Note. $R^2 = 0.4370$; Adjusted $R^2 = 0.4296$; $F(4, 196) = 58.42$, $p < 0.0001$. Dependent variable: Career path choice.

As shown in Table 4, multiple regression analysis was used to explore how intrinsic motivation, extrinsic motivation, the influence of third parties, and career exposure collectively affect accounting students' career path choices. The model as a whole is significant ($F(4, 196) = 58.42$, $p < 0.0001$) and accounts for 43.7% of the variance in career path choice ($R^2 = 0.437$, adjusted $R^2 = 0.430$). Of the four predictors, only intrinsic motivation ($\beta = 0.457$, $p < 0.0001$) and career exposure ($\beta = 0.265$, $p < 0.0001$) are statistically significant, with intrinsic motivation exerting nearly twice the standardized effect of career exposure. Third-party influence ($\beta = -0.065$, $p = 0.180$) and extrinsic motivation ($\beta = 0.102$, $p = 0.083$) are not significant predictors. This pattern is consistent with Social Cognitive Career Theory's emphasis on self-efficacy and personal interest as central drivers of career behavior, and it extends that theory by showing that direct exposure to the profession, rather than social pressure from family, peers, or teachers, is what translates interest into a concrete career choice. The non-significance of third-party influence departs from studies that found parental and peer influence to be important in other national contexts [22]–[24], but it aligns with research suggesting that outside influence carries less weight once students have direct, first-hand exposure to the accounting profession [27]. Similarly, the comparatively small and non-significant effect of extrinsic motivation implies that, in this sample, students are not primarily choosing accounting and finance careers for salary or job security, which is at odds with studies that identified pay and employment prospects as dominant motivators [13], [19], [20] and suggests that the balance between intrinsic and extrinsic drivers may be shifting as AI-related uncertainty changes how students weigh job security against personal fit with the profession. Taken together, these results indicate that curricula and career interventions aimed at strengthening students' direct exposure to accounting practice, rather than emphasizing pay or relying on third-party persuasion, are more likely to influence their career path choices. The unexplained 56.3% of the variance suggests that other factors not captured in this model, such as personality traits, prior academic performance, or students' direct experience with AI-enabled accounting tools, also play

a meaningful role and warrant investigation in future research.

4 CONCLUSION

The findings from this research provide valuable insights into the factors influencing the career pathways of accounting and finance students at a non-state university, Sri Lanka. The high level of intrinsic motivation identified in the study suggests that students are driven by personal interests and passions when considering their career options. This finding aligns with social cognitive career theory, which posits that individuals are more likely to pursue careers that resonate with their intrinsic values. Educational institutions could leverage this insight by offering programs and workshops that align academic experiences with students' personal interests, thereby fostering greater engagement and motivation. The role of extrinsic factors, such as salary and job security, was found in this study to be comparatively weak and statistically non-significant, in contrast to studies that identified pay and job security as dominant career motivators [13], [19], [20], and consistent with other studies showing that intrinsic motivation exerts a greater influence on career choice than extrinsic incentives [24]. Family, friends, and mentors are important in influencing students' profession choices; however, in this study third-party influence was not a statistically significant predictor, echoing a previous study that similarly concluded that peer, parental, and secondary-teacher influence was not an important determinant for accounting students [27]. The choice of job pathways is found to be significantly predicted by career exposure. Students consequently lack enough expertise and comprehensive information about job opportunities in the field of management accounting. According to this study, students' preferences for their career pathways are influenced by their exposure to the workforce. This underscores the importance of developing supportive networks around students. Educational institutions could implement mentorship programs that connect students with industry professionals, providing them with guidance and insight into various career paths. These findings should be read alongside the limitations discussed at the end of this paper.

5 IMPLICATIONS

The results of this study have significant implications for educational institutions, career counselors, and professional accounting bodies. By understanding the students' motivations and influences affecting students' career choices, institutions can design targeted programs highlighting their internal values. Students' motivation and engagement may rise when academic experiences are in line with their values and personal interests. Career exposure plays a critical role in their career choice. Educational institutions can improve career-related programs by focusing on intrinsic motivation, aligning academic experiences with students' interests, and providing practical experiences, mentorship programs, and industry interactions. Moreover, professional organizations can use these insights to refine recruitment strategies, ensuring they attract well-informed and motivated graduates. Even though social influences (family, peers, and teachers) and extrinsic motivations (such as pay and job security) have less of an impact than intrinsic motivation and career exposure, they still play a role in career decisions and ought to be considered in career counseling initiatives.

6 LIMITATIONS AND FUTURE RESEARCH

This study is not without limitations. First, data were collected from a single private university in Sri Lanka using convenience sampling, which limits the generalizability of the findings to accounting and finance students at other institutions or in other countries. Second, the cross-sectional design captures students' career intentions at a single point in time; it cannot establish causal relationships between the predictors and career path choice, nor can it capture how these intentions evolve as students approach graduation and enter the labor market. Third, the model explains 43.7% of the variance in career path choice, indicating that other relevant factors, such as personality traits, academic performance, or direct experience with AI-enabled accounting tools, were not captured and may further explain students' career decisions. Finally, all constructs were measured using self-reported Likert-scale items, which may be subject to

common method bias. Future research could address these limitations by adopting longitudinal designs, drawing on multi-institutional or cross-country samples, and incorporating additional variables, such as students' AI readiness or self-efficacy, to build a more comprehensive model of accounting and finance students' career path choice.

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The Impact of Occupational Stress on Retention of Tea Plantation Factory Officers: Evidence from the Nuwara-Eliya District, Sri Lanka

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ABSTRACT: Sri Lanka's tea sector earns significant foreign exchange, yet high turnover among factory officers threatens its future. Focusing on the Nuwara-Eliya district, this study examines how occupational stress across four dimensions job nature, role conflict and ambiguity, employee relationships, and external pressures shapes officers' intention to remain in their current role. A positivist, deductive, cross-sectional design underpins the analysis: 380 tea factory officers, drawn through stratified random sampling, completed a structured five-point Likert survey, and IBM SPSS 29 handled reliability testing, Pearson correlation, and multiple regression. Each stress dimension predicted retention intention significantly. Employee relationships carried the most weight ($\beta = 0.646$, $p < 0.001$), ahead of role conflict and ambiguity ($\beta = 0.354$, $p < 0.001$) and job nature ($\beta = 0.300$, $p < 0.001$), while external factors contributed a smaller, negative effect ($\beta = –0.094$, $p = 0.035$). Together the four predictors captured 76.2% of the variance in retention intention ($R^2 = 0.762$, $R = 0.873$, $F(4,375) = 300.16$, $p < 0.001$), and the measurement instrument held up well under reliability testing (Cronbach's $\alpha = 0.905$). Rural, agro-industrial settings like this one rarely feature in the Sri Lankan occupational-stress literature; the findings offer plantation managers concrete direction to redesign jobs, clarify roles, invest in workplace relationships, and strengthen employee welfare in order to keep the workforce stable.

Keywords: Employee retention, occupational stress, role conflict and ambiguity, Sri Lanka, tea plantation, workplace relationships

1 INTRODUCTION

A committed, stable workforce underpins not just individual organizations but the broader economy. Tea is among Sri Lanka's leading export earners and a major source of rural employment [1], yet production still relies on a traditional plantation model in which factory officers supervise manufacturing, coordinate labor, and safeguard quality. This importance is undercut by persistent officer turnover, which drains institutional know-how, inflates recruitment and training costs, and disrupts the production line [2].

Much of this turnover traces back to occupational stress: the psychological and physical toll that builds when job demands outstrip an employee's capacity to cope [3], [4]. Long shifts, seasonal production deadlines, understaffing, and irregular schedules compound this strain in tea factories, feeding absenteeism and dissatisfaction [4]. Layered on top, a rigid management hierarchy, thin communication channels, and recurring role conflict and ambiguity further erode officers' commitment over time [5]. Most stress-and-turnover research to date sits in urban or service-sector contexts, Sri Lanka's banking industry among them [6], while rural, agro-industrial roles such as tea factory supervision remain comparatively overlooked, particularly in high-altitude districts like Nuwara-Eliya, where punishing

working conditions meet relative isolation. Nuwara-Eliya was selected purposively as the study site because it is Sri Lanka's principal high-grown tea district, home to some of the country's oldest and largest tea factories, including the Damro Labookellie, Pedro, and Blue Field estates [17], and because its high-altitude climate, remoteness, and concentration of factory officers plausibly intensify several of the stress dimensions examined here harsh working conditions, long commutes, and limited external amenities in ways not replicated in mid- or low-grown districts. This makes Nuwara-Eliya a theoretically relevant and information-rich site for studying occupational stress and retention in the plantation sector, even though its single-district focus limits generalizability, a point revisited in the concluding section.

Two questions guide the analysis that follows: what are the principal sources of occupational stress facing tea factory officers in Nuwara-Eliya, and how do these specific stressors relate to their retention? The answers carry weight beyond academic interest, speaking directly to Sustainable Development Goal 8 (Decent Work and Economic Growth) and to the human-resource policy choices facing one of Sri Lanka's most economically vital industries.

2 LITERATURE REVIEW

2.1 *Occupational Stress: Conceptual Background*

Occupational stress can be understood as the damaging emotional and physical reaction that follows when the demands of a job outpace what an employee is equipped to handle [7]. Early facet-based models tie this mismatch to poorer employee health and reduced organizational performance [8], and subsequent theory frames stress more broadly as friction between environmental pressures and an individual's ability to cope [9]. Drawing on this foundation, the present study groups occupational stress in Sri Lanka's tea sector under four headings job nature, role conflict and ambiguity, employee relationships, and external pressures a grouping that aligns with prior research linking these same factors to dissatisfaction and attrition among tea-factory staff [4].

2.2 *Theoretical Framework*

This study is anchored in the Job Demands–Resources (JD–R) model [7], [9], which frames occupational strain as arising when job demands workload, role pressures, interpersonal friction, and external life pressures exceed the resources available to the employee, and links a sustained imbalance to withdrawal outcomes such as turnover intention. The model's demand–resource logic supplies the theoretical rationale for treating job nature, role conflict and ambiguity, employee relationships, and external factors as four distinct demand clusters, each capable of independently eroding an officer's capacity and willingness to remain. Role theory [11] supplements the JD–R framework specifically for the second dimension, explaining why unclear or contradictory expectations generate strain distinct from workload alone. Together, the JD–R model as the overarching framework and role theory as a supporting lens for H2 justify grouping the four independent variables (Fig. 1) and predicting their combined bearing on retention.

2.3 *Nature of the Job*

Job characteristics are frequently the first and most direct source of strain. For tea factory officers this covers unmanageable workloads, monotonous tasks, exposure to heat, dust, and loud machinery, and inadequate rest periods pressures that intensify sharply once the plucking season demands longer shifts to meet export targets [4]. Comparable plantation research confirms that punishing conditions and extended hours correlate closely with elevated stress and eventual exit [10]. Poorly managed job design, in turn, leaves officers less satisfied and less inclined to stay long-term.

2.4 *Role Conflict and Ambiguity*

Ambiguity sets in whenever employees are left without a clear sense of their duties or reporting lines; long-standing role theory shows that this uncertainty erodes satisfaction and raises stress levels [11]. Conflict, meanwhile, surfaces when officers are handed contradictory directives asked, say, to lift output while simultaneously tightening quality control. Both patterns chip away at confidence and push officers toward the exit [12], a risk compounded for those bal-

ancing administrative, technical, and supervisory duties without sufficient training [4].

2.5 *Relationships between Employees*

The quality of workplace relationships is repeatedly singled out as a key driver of both satisfaction and retention. Within the plantation sector's steep hierarchies, strained ties with supervisors, peers, or subordinates undermined by weak communication or distrust intensify stress considerably, whereas supportive supervision and cooperative peer dynamics ease strain and build commitment across organizational contexts generally [12]. Sri Lankan plantation case evidence points to interpersonal and managerial dynamics as a decisive factor behind officers' decisions to stay [13], and separate work on HRM practices in the tea sector spanning welfare, training, and career progression likewise ties supportive management to firmer retention [5].

2.6 *External Factors*

Pressures originating outside the workplace family obligations, financial strain, and restricted access to healthcare and transport tend to draw less scholarly attention than internal stressors, yet their effect is far from trivial. Conflict between work and personal life reliably predicts turnover in roles marked by long or unpredictable hours [14]. Evidence from Sri Lankan plantations echoes this, linking difficult commutes and sparse social amenities to weaker retention [15], a problem sharpened by how closely officers' living quarters sit to their place of work, blurring the line between job and home life [16].

2.7 *Identification of the Independent Variables and Research Gap*

The four stress dimensions examined here were not selected arbitrarily. Job nature, role conflict and ambiguity, and employee relationships are drawn directly from the tea-sector evidence of Arachchige [4], the most directly comparable Sri Lankan study identified in the literature, while external factors is added following Sparks and Cooper [14] and the Sri Lankan plantation evidence of Sanjeewa and Ranasinghe [15] and Subasinghe and Rathnayake [16], since work–life and community-level pressures recur throughout the plantation-sector literature but were not incorporated in Arachchige's original model. This combination keeps the framework grounded in sector-specific evidence while extending it to capture pressures unique to remote, high-altitude estates such as those in Nuwara-Eliya.

The resulting gap is significant: Arachchige [4] and Abesiri and Jayasekara [5] both point to elevated stress and weak retention practices in the tea sector, but neither directly models specific stress dimensions against a validated retention outcome using multivariate methods, and neither extends to Nuwara-Eliya's high-altitude estates specifically. By explicitly testing four theoretically grounded stress dimensions against officers' retention intention in this under-studied context, the present study offers a JD–R-grounded, quantitative account of stress-driven retention risk in Sri Lanka's high-grown tea sector.

2.8 *Occupational Stress and Retention: Synthesis*

Taken together, this body of work casts occupational stress as a multi-faceted force behind retention in labor-intensive, hierarchical sectors such as tea plantations, even though most of the underlying evidence comes from urban or service-industry contexts, or from plantation studies oriented toward satisfaction rather than retention outcomes specifically [4], [6]. Four hypotheses follow from this framework, each proposing a significant link between one stress dimension and officer retention: job nature (H1), role conflict and ambiguity (H2), relationships between employees (H3), and external factors (H4).

3 METHODOLOGY

3.1 *Research Design and Philosophy*

Occupational stress and retention are treated here as an objective, measurable relationship, consistent with a positivist stance and captured through quantitative rather than interpretive methods. Rather than build new theory, the analysis deduces its predictions from the JD–R framework and role theory set out in Section II-B. A single quantitative instrument a structured questionnaire survey supplies the data, gathered between March

2025 and December 2025 (approximately ten months), with each individual tea plantation factory officer treated as the unit of analysis. Ethical approval for this study was obtained from the Research Ethics Committee, Faculty of Business, NSBM Green University and all respondents were informed of the study's purpose and gave consent before completing the questionnaire; participation was voluntary and anonymous throughout, with no identifying information collected.

3.2 *Conceptual Framework*

Fig. 1 sets out the conceptual model: the four independent variables job nature, role conflict and ambiguity, employee relationships, and external factors are proposed as drivers of the dependent variable, retention (intention to stay) of tea plantation factory officers.

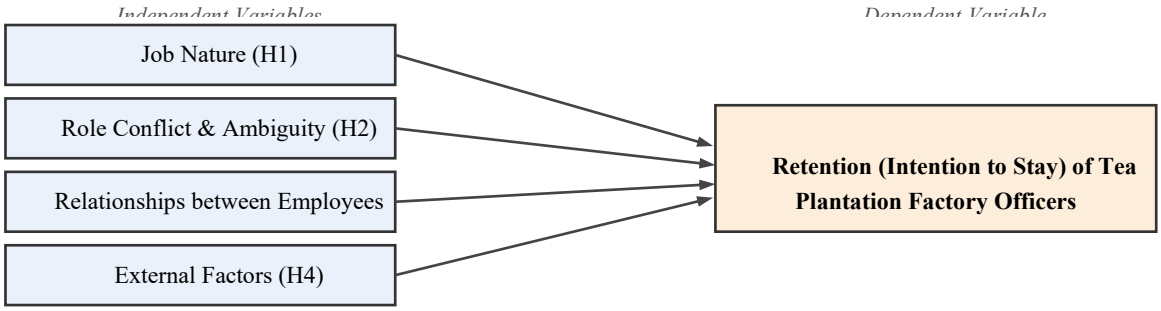


Figure 1. Conceptual framework

3.3 *Population and Sample*

The target population comprised non-executive and junior-executive grade factory officers directly engaged in day-to-day production supervision, quality control, and labor coordination at tea estates across the Nuwara-Eliya district among them the Damro Labookellie, Pedro, and Blue Field factories [17] including roles such as junior assistant factory officers, shift supervisors, and quality control officers; senior estate- and company-level management staff were excluded, since their working conditions and retention determinants differ materially from front-line factory-floor officers. The sampling frame comprised approximately 430 officers meeting these criteria across the three estates. Questionnaires were distributed to the full frame using stratified random sampling proportional to job grade, and 380 usable responses were returned, a response rate of 88.4%.

3.4 *Instrument and Data Collection*

An online, structured questionnaire gathered the data in two parts. The first recorded demographic details gender, age, marital status, education, job position, service length, and monthly income while the second measured the four independent variables and the retention outcome across 25 statements (five per construct), rated on a five-point scale running from 1 (strongly disagree) to 5 (strongly agree). Items measuring the four stress dimensions were adapted from validated instruments used in comparable Sri Lankan tea-sector and occupational-stress research, principally Arachchige [4] for job nature, role conflict and ambiguity, and employee relationships, and Sparks and Cooper [14] for external/work–life factors; retention items were adapted from Abesiri and Jayasekara [5]. All items were reviewed for content validity by two senior academics in human resource management, and piloted with 30 officers (not included in the final sample) before the main survey, with minor wording changes made for clarity following the pilot.

3.5 *Data Analysis*

IBM SPSS Statistics version 29 handled the analysis: Cronbach's alpha for reliability, descriptive statistics to profile the sample and variables, Pearson correlation to gauge bivariate associations, and multiple linear regression to test H1 through H4. Prior to hypothesis testing, the data were screened for normality (skewness and kurtosis within ±1), linearity, and homoscedasticity via residual plots, and multicollinearity was

checked using tolerance and VIF statistics; all assumptions were satisfied.

4 RESULTS

4.1 *Sample Profile*

Men made up 95% of the 380 respondents (n = 361), and 71.3% were married. Officers aged 31–40 formed the largest age band (44.2%). G.C.E. Advanced Level was the most common qualification (46.3%), and junior assistant factory officer the most common role (43.7%); 42.5% had served between six and ten years, and 40% earned between Rs. 40,000 and Rs. 50,000 monthly.

4.2 *Reliability Analysis*

Cronbach's alpha assessed internal consistency: the full 25-item instrument scored an excellent 0.905 overall. Table 1 breaks this down by construct every one clears the conventional 0.7 threshold, supporting the instrument's reliability.

Table 1. Reliability statistics by construct

Construct	Items	Cronbach's α	Interpretation
Nature of job	5	0.724	Good
Role conflict and ambiguity	5	0.746	Good
Relationships between employees	5	0.815	Very good
External factors	5	0.704	Good
Retention	5	0.755	Good
Overall instrument	25	0.905	Excellent

4.3 *Descriptive Statistics*

Table 2 summarizes the study variables. All five means sit above 4.0 with standard deviations under 0.33, pointing to broad agreement that each stress dimension carries real weight in officers' working lives. Employee relationships posted the highest mean (4.29), ahead of retention (4.15), role conflict and ambiguity (4.10), job nature (4.04), and external factors (4.02).

Table 2. Descriptive statistics of study variables (N = 380)

Variable	Min	Max	Mean	SD
Nature of job	2.47	5.00	4.04	0.302
Role conflict and ambiguity	2.30	5.00	4.10	0.318
Relationships between employees	2.30	5.00	4.29	0.328
External factors	2.30	5.00	4.02	0.302
Retention	2.30	5.00	4.15	0.317

4.4 *Correlation Analysis*

Table 3's Pearson correlations confirm that each independent variable relates positively and significantly to retention ($p = 0.001$ throughout). Employee relationships shows the tightest link ($r = 0.789$, a strong correlation); job nature ($r = 0.636$), role conflict and ambiguity ($r = 0.573$), and external factors ($r = 0.443$, the weakest) follow at a moderate level.

Table 3. Pearson correlation with retention

Variable	r	Sig. (2-tailed)	Strength
Nature of job	0.636	0.001	Moderate
Role conflict and ambiguity	0.573	0.001	Moderate
Relationships between employees	0.789	0.001	Strong
External factors	0.443	0.001	Moderate

4.5 *Regression Analysis and Hypothesis Testing*

The four-predictor model reaches statistical significance, $F(4, 375) = 300.16$, $p < 0.001$, accounting for 76.2% of the variance in retention ($R = 0.873$, $R^2 = 0.762$, adjusted $R^2 = 0.759$, SE = 0.175). Coefficients for each predictor appear in Table 4. Employee relationships again leads ($\beta = 0.646$, $p < 0.001$), followed by role conflict and ambiguity ($\beta = 0.354$, $p < 0.001$) and job nature ($\beta = 0.300$, $p < 0.001$); external factors register a smaller negative coefficient ($\beta = –0.094$, $p = 0.035$). Tolerance above 0.39 and VIF below 2.6 across all predictors rule out problematic multicollinearity.

Table 4. Regression coefficients (dependent variable: retention)

Predictor	B	SE	β	t	Sig.
(Constant)	0.757	0.147	–	5.14	<0.001
Nature of job	0.290	0.046	0.300	6.36	<0.001
Role conflict and ambiguity	0.354	0.086	0.354	4.11	<0.001
Relationships between employees	0.622	0.089	0.646	7.01	<0.001
External factors	–0.094	0.044	–0.094	–2.11	0.035

The resulting regression equation for predicting retention (Y) from the four stress dimensions (X_1 = nature of job, X_2 = role conflict and ambiguity, X_3 = relationships between employees, X_4 = external factors) is:

$$Y = 0.757 + 0.290X_1 + 0.354X_2 + 0.622X_3 - 0.094X_4 \quad (1)$$

Every predictor's significance value falls below 0.05, so the null hypothesis is rejected in each case. At 95% confidence, H1 through H4 all hold: each of the four stress dimensions bears a statistically significant relationship to the retention of tea plantation factory officers in Nuwara-Eliya.

5 DISCUSSION

Across all four dimensions, occupational stress emerges as a strong driver of retention intention among tea plantation factory officers. The dependent variable in this study captures officers' self-reported intention to remain in their current role rather than observed turnover behavior; as in most single-time-point surveys, intention is used as a proxy for actual retention, but the two do not always align perfectly, and this distinction is revisited in the limitations below. Employee relationships stand out as the single strongest predictor, echoing earlier findings that interpersonal dynamics and managerial ties sit at the heart of commitment within plantation hierarchies [13]. Supportive supervisory networks appear to let officers absorb heavy workloads without disengaging; where those relationships fray, turnover intentions climb quickly a pattern consistent with the broader view of social support as a buffer against stress [12], and with the resource side of the JD–R model in particular.

Job nature shows a moderate but statistically solid link to retention, tracking the demanding conditions long hours, poor ventilation, heat, dust, and seasonal workload surges inherent to tea manufacturing [4], [10]. These conditions are baked into the job's structure, so meaningful change would require deliberate redesign and investment in the factory environment itself. Role conflict and ambiguity likewise add meaningfully to stress and, by extension, to weaker retention. Officers juggling administrative, technical, and supervisory responsibilities often under contradictory direction face persistent uncertainty that saps confidence, a dynamic long documented in role theory [11]. Sharper job descriptions and steadier supervisor feedback would go some way toward easing this pressure.

External factors carry the weakest, and notably negative, weight in the regression model. Rather than implying that external pressures increase officers' willingness to stay, this coefficient more plausibly reflects the limited alternative employment available to officers coping with financial strain or restricted transport in a remote, high-altitude district: officers facing the heaviest external pressures may feel more economically tied to their current post, reporting higher retention intention despite not because of those pressures. This reading is consistent with a resource-scarcity rather than a resource-support account within the JD–R model, and it tracks cross-national evidence tying work–life conflict to turnover [14] and Sri Lankan findings on the toll of limited housing, healthcare, and transport in rural estate communities [15], [16]. These pressures sit outside the factory gate but remain within reach of employer support welfare schemes, housing allowances, transport assistance.

With 76.2% of the variance in retention intention accounted for, occupational stress clearly ranks as a substantial force behind workforce stability here. Because the data are cross-sectional, however, these associations describe concurrent patterns rather than causal effects; the practical implications below should be read as theoretically grounded directions for HR practice rather than as causally guaranteed outcomes of any single intervention. Extending stress research into a rural, agro-industrial setting long overshadowed by urban service-sector work [6], the findings nonetheless point practically toward job redesign, clearer

roles, relationship-building training, and welfare support as levers for reducing turnover risk, in line with established HR guidance [18], [19]. Left unattended, these pressures threaten to keep turnover high and erode Sri Lanka's competitive standing in the global tea trade.

6 CONCLUSION AND RECOMMENDATIONS

Occupational stress spanning job nature, role conflict and ambiguity, employee relationships, and external factors substantially shapes retention intention among tea plantation factory officers in Nuwara-Eliya, Sri Lanka. Drawing on a large, well-validated sample of officers, the analysis finds all four dimensions to be significant predictors of retention intention, with employee relationships the single strongest factor. Beyond pay or title, then, the relational texture of daily work appears central to whether officers intend to stay.

These findings point plantation management toward several practical steps. First, jobs and workloads should be redesigned through structured shifts, adequate rest periods, and safety and ventilation upgrades, especially during peak plucking season, since job-nature pressures are structurally embedded in the production cycle and require deliberate investment rather than incremental fixes. Second, role clarity should be sharpened through detailed, regularly updated job descriptions, realistic performance targets, and structured onboarding for officers who juggle administrative, technical, and supervisory duties. Third, management should invest systematically in relationship-building, including supervisor training in people management, mentorship pairing for newer officers, and formal, accessible conflict-resolution channels, given that employee relationships emerged as the strongest predictor of retention intention. Fourth, welfare and external support such as subsidized transport, housing assistance, and family-oriented welfare schemes should be extended to offset the isolation and cost pressures particular to high-altitude estates. Finally, these interventions should be embedded within a broader HR strategy that links stress reduction explicitly to retention and career-development planning, rather than treating it as a standalone wellness initiative.

Two limitations temper these conclusions: the cross-sectional design, which captures association rather than causation and measures intention to stay rather than observed turnover, and the single-district scope, which limits generalizability beyond Nuwara-Eliya's high-altitude estates. Future research could pair these quantitative findings with qualitative accounts of officers' lived stress experiences, track actual retention outcomes longitudinally against baseline stress measures, and extend the analysis to additional tea-growing districts for comparison.

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MASS Adoption Readiness in Developing Maritime Nations: an Integrated Techno-Governance Framework

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ABSTRACT: This paper develops a conceptual framework for examining Maritime Autonomous Surface Ship (MASS) adoption readiness in developing maritime nations. A transparent, focused evidence synthesis combines peer-reviewed MASS research with International Maritime Organization (IMO) instruments. Sources were selected when they directly addressed operational technology, national preparedness, regulation, legal accountability, cyber risk, or workforce capability. The synthesis distinguishes adoption, readiness, and maturity, then organizes the evidence into a five-enabler technology domain and a five-enabler governance domain. The domains were first derived through thematic coding and then deliberately coupled through operational-dependence rules. Sri Lanka is used only to demonstrate how the framework can structure a future country assessment; the paper does not present a measured national readiness score. The resulting framework identifies the evidence that a future assessment must collect, the dependencies that must be tested, and a staged policy sequence aligned with the IMO MASS Code roadmap. Its contribution is therefore a proposition for evidence-based assessment and policy design, rather than an empirical evaluation of Sri Lankan readiness.

Keywords: Maritime Autonomous Surface Ships, MASS, autonomous shipping, readiness, maritime governance, developing maritime nations, Sri Lanka, IMO MASS Code

1 INTRODUCTION

Maritime Autonomous Surface Ships (MASS) range from ships with automated decision support and crew aboard to ships able to operate independently of direct human interaction [1]. Their development is reshaping vessel operation, shore-side control, port interfaces, and safety regulation. In May 2026, the IMO adopted the non-mandatory MASS Code, which entered into force on 1 July 2026 [6]. The Code establishes a goal-based and technology-neutral framework for the safe design, construction, operation, and certification of MASS, while retaining human responsibility for the ship and requiring risks to be identified and managed [6].

The Code does not make national preparation optional in practical terms. It is intended to inform a future mandatory instrument, with the IMO roadmap targeting adoption by 1 July 2030 and entry into force on 1 January 2032 [6]. For developing maritime nations, the challenge is not limited to acquiring autonomy technologies. It also includes legal accountability, flag-state capability, cyber-risk management, training, and coordination among national maritime institutions.

1.1 *Why developing maritime nations face distinct stakes*

Much of the MASS feasibility and technology literature has been developed in advanced maritime economies [1], [2]. Devel-

oping maritime nations often face different infrastructure, institutional, and workforce conditions. Readiness conclusions cannot therefore be transferred directly from early-adopter contexts. Recent research also shows that the human consequences of MASS extend beyond employment to task redesign, skills, regulation, and training systems [9]. A readiness framework for these contexts must treat technology and governance as interdependent conditions rather than separate checklists.

1.2 *Sri Lanka and the strategic value of hub position*

Sri Lanka is used in this paper as a contextual illustration of how the framework can guide a future country assessment. It is not treated as an empirical case study and no national readiness score is claimed. This distinction matters because a valid assessment would require primary evidence from port authorities, the flag administration, maritime education institutions, operators, insurers, and other stakeholders.

1.3 *Aim, research questions, and contribution*

This paper develops and demonstrates an integrated framework for examining MASS adoption readiness in developing maritime nations. It asks: (1) what evidence is relevant to MASS readiness in such settings; (2) how can technological and governance conditions be connected without conflating them; and (3) how can the framework guide an evidence-based future application in Sri Lanka? The contribution is a conceptual assessment architecture, a transparent source-selection and coding procedure, and a proposed policy sequence aligned with the IMO roadmap.

2 LITERATURE REVIEW

2.1 *MASS technology and degrees of autonomy*

MASS relies on integrated sensing, navigation, control, communications, and human oversight. The IMO taxonomy recognizes degrees ranging from automated decision support with crew aboard to fully autonomous operation [1]. The operational challenge is not the presence of a single sensor or algorithm. It is the ability of the overall system, including a remote operating centre (ROC) where relevant, to achieve an equivalent level of safety under defined operating conditions [1], [6].

2.2 *IMO regulatory evolution: from scoping exercise to Code*

The IMO Regulatory Scoping Exercise examined how existing instruments would apply to MASS and exposed issues that require clarification or adaptation [7]. The resulting MASS Code provides a voluntary, goal-based framework and links operational authorization to risk management, defined modes of operation, human responsibility, and safe ROC arrangements [6]. The continuing regulatory work confirms that implementation depends on more than vessel technology. It also requires coordinated action across safety, legal, facilitation, and environmental instruments.

2.3 *Adoption and feasibility models*

Feasibility and adoption research provides complementary perspectives. Munim et al. identify safety, operating cost, and capital cost as influential in commercial feasibility, particularly for lower-degree autonomy in feeder operations [2]. Fonseca et al. show that innovation adoption also depends on environmental and social conditions, including regulation, governance, acceptance, and human capital [3]. These studies justify examining technical capability together with institutional capability, while keeping the concepts analytically distinct.

2.4 *Stakeholder and readiness studies*

Stakeholder and national-preparedness studies further show that readiness is multidimensional. Theotokatos et al. identify divergent stakeholder views and priority gaps for next-generation shipping [4]. De Klerk et al. examine national preparedness through policy, legislation, societal readiness, and human-resource development [8]. A recent Southeast Asian readiness study also illustrates the use of a regional index and phased roadmap for MASS adoption [5]. These studies inform the framework but do not supply empirical evidence about Sri Lanka.

2.5 *Smart ports, digitalisation, and cybersecurity*

MASS moves part of the operational burden ashore, making port interfaces, communications, and cyber resilience integral to safety. IMO cyber-risk guidance treats maritime cyber risk as an operational, safety, and security concern and recommends an ongoing risk-management process for technology assets and connected systems [12]. Accordingly, cyber-physical resilience is included as a readiness condition rather than as a secondary technical feature.

2.6 *Human capital and the displacement debate*

The human dimension is equally central. A systematic review of human-centred MASS research identifies implications for employment, task content, skills, and human risks [9]. Recent reviews of MASS operator competence also emphasize operational, digital, cognitive, and collaborative capabilities [11]. The framework therefore treats workforce transition as a governance and capability question requiring evidence about education, certification, and institutional support, not as a forecast of job displacement.

3 RESEARCH GAP

The evidence base indicates a conceptual gap rather than proof of a national performance gap. Existing research contains strong technology, feasibility, stakeholder, and regulatory strands, but it commonly analyzes these strands separately. It also provides limited directly comparable evidence for developing maritime nations. The present framework responds by specifying how technological and governance evidence should be assembled and connected before a jurisdiction is assigned a readiness position. Table 1 records the focused evidence base used for this purpose.

The framework is therefore a conceptual proposition. It should be evaluated through country-specific primary data, documentary verification, and stakeholder validation before being used to make a national readiness claim.

Table 1. Focused evidence base used in the framework synthesis

Evidence group	Sources	Inclusion basis	Use in the framework
IMO instruments	[6], [7], [12]	Primary regulatory or guidance document	Operational authorization, regulatory alignment, cyber-risk conditions
Technology and feasibility	[1], [2]	Peer-reviewed MASS study	Vessel systems, operating conditions, feasibility constraints
Adoption and stakeholders	[3], [4]	Peer-reviewed MASS study	Governance, acceptance, stakeholder priorities
National readiness	[5], [8]	Peer-reviewed or documented readiness study	Assessment dimensions and staged preparation
Law and human capability	[9], [10], [11]	Peer-reviewed review or legal analysis	Workforce, competence, accountability, flag-state issues

4 METHODOLOGY

This study uses a focused integrative evidence synthesis and conceptual framework-construction design. It is not a systematic review or an empirical readiness assessment. The initial corpus was expanded with current peer-reviewed studies and primary IMO instruments to cover six domains: operational technology, national preparedness, regulation, legal accountability, cyber risk, and workforce capability. The unit of analysis was a source's explicit treatment of an enabling condition or dependency relevant to MASS adoption readiness.

Sources were included when they were peer-reviewed MASS studies or authoritative IMO instruments published between 2015 and 2026, written in English, and directly relevant to at least one of the six domains. Sources were excluded when they addressed autonomous systems without implications for maritime adoption readiness, duplicated a more directly relevant review, or lacked sufficient bibliographic information for verification. The selected evidence base is shown in Table 1. This transparent protocol is deliberately narrower than a PRISMA-style systematic review and does not support prevalence claims about the full literature.

Thematic coding proceeded in two stages. First, source statements were coded inductively as technological, governance, or cross-cutting human-capital conditions. Repeated concepts were consolidated into five technology enablers and five governance enablers. Second, the coupling relationships were specified deliberately, not assumed to have emerged automatically. A link was retained only where the evidence indicated that one condition could not be operationally useful, safely authorized, or sustainably scaled without the other. Table 2 reports the resulting codebook and the principal dependencies.

The concepts are kept separate throughout the paper. Adoption is the decision and process of introducing MASS into a maritime system. Readiness is the present capacity to undertake that process safely and lawfully. Maturity is the staged level of development observed after readiness evidence is assessed. The four maturity labels used here - Nascent, Emerging, Transitional, and Operational - are descriptive categories for future application. They are not scores, and this paper assigns none to Sri Lanka or to any country group.

5 PROPOSED INTEGRATED TECHNO-GOVERNANCE FRAMEWORK

5.1 *Architecture*

The framework has two analytically distinct but operationally interdependent domains: a technology domain and a governance domain. The technology domain contains vessel autonomy and navigation, ROC capability, connectivity and information exchange, smart-port interface, and cyber-physical resilience. The governance domain contains legal and regulatory alignment, liability and accountability, certification and competence, institutional coordination, and workforce transition. Figure 1 illustrates the architecture. The framework does not average these conditions into a single score.

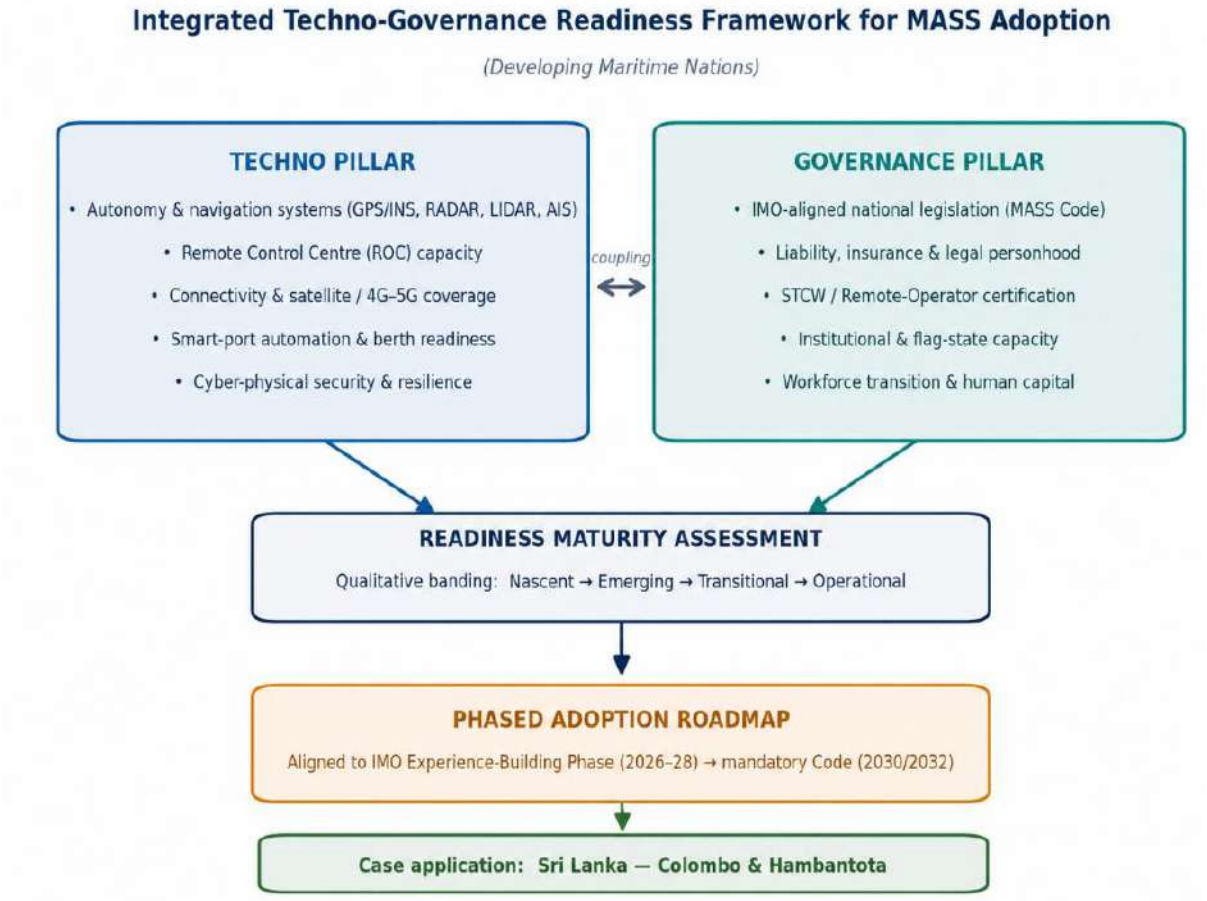


Figure 1. Integrated techno-governance framework for conceptual MASS readiness assessment

The technology domain captures the operational capability required for the intended MASS mode. Vessel systems cover sensing, navigation, and control. ROC capability covers shore-side supervision and intervention. Connectivity covers the reliability of ship-shore information exchange. The smart-port interface covers the operational and digital interfaces needed at ports. Cyber-physical resilience covers the protection and recovery of connected operational systems. These categories were retained because the literature and IMO instruments consistently treat them as conditions for safe operations [1], [2], [6], [12].

The governance domain captures the authority and capacity that make technical capability deployable. Legal and regulatory alignment concerns domestic implementation of relevant international obligations. Liability and accountability concern the allocation of responsibility among the master, operator, owner, and other actors. Certification and competence address the qualifications needed for remote and automated operations. Institutional coordination concerns the ability of maritime authorities and ports to authorize, supervise, and learn from operations. Workforce transition concerns education, reskilling, and institutional support for changing roles [6], [8], [10], [11].

Coupling is a second-order analytical rule. It does not merge technology and governance into the same variable. Instead, it tests dependencies. For example, ROC capability requires competent operators and an authorization pathway. Connectivity requires cyber-risk management and institutional oversight. Advanced vessel systems require legal clarity about responsibility. A future assessment should record evidence for each enabler, test the dependencies in Table 2, and assign a maturity category only after stakeholders validate the evidence. A maturity weakness in a critical dependency cannot be offset by an unrelated technology strength.

6 FRAMEWORK DEMONSTRATION AND IMPLICATIONS

Table 2 presents the evidence codebook produced by the synthesis. It is not a comparison of observed readiness between advanced and developing maritime nations. The table indicates the evidence and dependency that a future assessment should examine. This change avoids treating literature-derived generalizations as measured country data.

Table 2. Technology and governance codebook with principal operational dependencies

Technology enabler	Governance dependency	Evidence to collect
Vessel autonomy and navigation	Legal alignment and liability	Intended autonomy mode, risk controls, responsibility allocation
ROC capability	Certification and institutional coordination	ROC procedures, operator competence, authorization and supervision
Connectivity and information exchange	Cyber-risk management	Coverage, reliability, access control, response and recovery
Smart-port interface	Institutional coordination	Port procedures, traffic interfaces, interoperability and approval roles
Cyber-physical resilience	Competence and accountability	Asset protection, incident response, roles, training and assurance

Sri Lanka is used to demonstrate the sequence of a future application, not to report a readiness result. An application would first define the operating context, including vessel type, degree of autonomy, route, and relevant port interface. It would then assemble evidence from official documents, site observations, and stakeholder interviews. The framework would be used to identify missing evidence and dependencies before any maturity placement is proposed.

6.1 *Implications of the coupled framework*

The framework has three implications for developing maritime nations. First, technology investment alone cannot establish readiness where legal accountability, institutional authority, or competence requirements are unresolved. Second, a readiness study should make evidence gaps visible instead of filling them with illustrative ratings. Third, the framework can help sequence in-

vestment by identifying dependencies that must be resolved before trials or scaled operations can be safely considered [6], [8], [10].

The revised IMO roadmap provides a time-bounded policy context. The non-mandatory Code is now in force, the IMO plans to develop the Experience-Building Phase framework at MSC 112 in December 2026, and the mandatory Code is targeted for adoption by 1 July 2030 and entry into force on 1 January 2032 [6]. A developing maritime nation can use the framework to organize evidence collection and policy preparation during this period, without representing preparatory activity as proof of readiness.

7 POLICY AND OPERATIONAL RECOMMENDATIONS

The framework suggests a staged preparatory sequence aligned with the IMO roadmap. The sequence is a policy proposition, not a forecast or a finding about Sri Lanka. It prioritizes evidence collection, governance preparation, controlled learning, and subsequent scale-up only where validated evidence permits.

Stage 1 2026 to 2028 Foundation. Define the intended operating context and collect baseline evidence across the ten enablers. Review domestic legislation against the MASS Code and the Regulatory Scoping Exercise. Establish a cross-institutional governance group and identify the documentary, technical, and stakeholder evidence needed for a future readiness assessment [6], [7].

Stage 2 2028 to 2030 Controlled learning. Where national authorization and risk controls permit, design limited supervised trials with explicit operating conditions, ROC arrangements, cyber-risk controls, and competency requirements. Use the evidence generated to revise institutional procedures and the readiness evidence register. No trial should be treated as a substitute for legal, certification, or safety assurance [6], [12].

Stage 3 2030 to 2032 Regulatory alignment. Prepare domestic rules, accountability arrangements, competence pathways, and institutional responsibilities for the anticipated mandatory Code. Validate the framework with regulators, port operators, educators, insurers, and workforce representatives. Any decision to expand operations should be based on the validated evidence, not on the conceptual categories alone [6], [10], [11].

Stage 4 2032 onward Continuous review. Maintain a periodic evidence review as IMO requirements, technologies, cyber threats, and workforce needs evolve. The purpose is to keep readiness assessment connected to observed operational performance and regulatory change rather than treating it as a one-time classification.

8 CONCLUSIONS

This paper develops a conceptual framework for MASS adoption readiness in developing maritime nations. It avoids presenting a framework demonstration as an empirical country assessment. The evidence synthesis distinguishes adoption, readiness, and maturity, states explicit source-selection criteria, and explains how the ten enablers were coded and then deliberately coupled. The resulting framework treats technological capability and governance capability as separate but interdependent conditions [1], [3], [6], [8].

Sri Lanka remains an illustrative context for future application, not a source of reported readiness findings. A valid application requires a defined MASS operating context and verified primary evidence from relevant institutions and stakeholders. The framework can then support a transparent account of what evidence exists, what dependencies are unresolved, and what policy sequence is appropriate.

The principal limitation is therefore deliberate and explicit: this is a conceptual, non-empirical study. Future research should conduct document verification, expert interviews, and structured stakeholder validation before assigning maturity categories or making recommendations about a specific jurisdiction. That work would permit the framework to be tested, refined, and, if warranted, converted into a calibrated assessment instrument.

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Leader Voice Endorsement Transparency and Employee Voice Behaviour: The Moderating Role of Employee Workplace Status in the Sri Lankan Information Technology Sector

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ABSTRACT: Employees' voice behaviour is increasingly recognized as an important source of information sharing, problem identification, innovation, and organizational learning. Drawing on Social Exchange Theory, this study examines the relationship between leader voice endorsement transparency and employee voice behaviour in the Sri Lankan Information Technology (IT) sector and tests whether employee workplace status moderates this relationship. Using a deductive quantitative design, data were collected from 235 employees through convenience sampling and analyzed using SPSS. Pearson correlation, linear regression, and moderation analysis were conducted. The results show a strong positive association between leader voice endorsement transparency and employee voice behaviour ($r = .61$, $p < .01$), and regression analysis indicates that leader voice endorsement transparency is a significant positive predictor of employee voice behaviour ($B = .55$, $\beta = .55$, $p < .001$). Employee workplace status also shows a significant positive main effect in the moderation model ($B = .21$, $\beta = .18$, $p < .001$). However, the interaction between leader voice endorsement transparency and workplace status is not statistically significant ($B = -.06$, $\beta = -.07$, $p = .100$). Therefore, H1 is supported, whereas H2 is not supported. The interaction coefficient is negative and does not provide evidence that the relationship is stronger for low-status employees or weaker for high-status employees. The findings therefore support the value of transparent leader communication as a predictor of employee voice, while not establishing workplace status as a boundary condition in this sample. The study contributes to the voice literature by examining leader voice endorsement transparency in a Sri Lankan IT context and by reporting a theoretically plausible but unsupported moderation hypothesis without overstating the statistical evidence. Practically, the findings suggest that organizations should make the criteria and reasoning used to evaluate employee suggestions clearer and provide consistent feedback across employees.

Keywords: Employee voice behaviour, Employee workplace status, Information Technology (IT) sector, Leader voice endorsement transparency, Social Exchange Theory (SET)

1 INTRODUCTION

Employee voice behaviour refers to the proactive expression of work-related ideas, concerns, or suggestions to improve other aspects of organizational functioning [22], [23] and is a vital source of innovation, flexibility, and effectiveness in organizational decision-making [2]. This is especially important for Sri Lankan IT firms, which are driven by rapid changes in technology and global competition that require the constant generation of ideas, the dissemination of information, and the active participation of employees. Despite recognizing the value of employee voice, many organizations continue to struggle with a critical issue: employees are sometimes reluctant to voice their

opinions because of their apprehensions about how leaders will appraise and respond to their suggestions [9], [27].

Existing research highlights several factors that influence leaders' endorsement of employee voice, such as the quality of employee suggestions [4], leader traits [8], [31], and characteristics of the employee who speaks up [21]. Yet, little attention has been paid to an important aspect: the clarity of the leader in communicating how he/she evaluates and endorses employee voice. This results in an endorsement "black box", which constrains employee comprehension of what makes good suggestions, and prevents greater engagement in voice behaviours [24].

To fill this gap, this study draws attention away from whether or not the endorsement happens, or the endorsement "event", and onto the transparency of the endorsement process, defined as leader voice endorsement transparency. Leader voice endorsement transparency refers to the degree of transparency around the criteria and decision-making process for endorsement by leaders. This study uses Social Exchange Theory to suggest that when leaders communicate transparently, it is a strong social signal that communicates social cues, which lessen the uncertainty and guide employee behaviour. Employees better understand the endorsement criteria and expectations with which to align their ideas and engage in constructive voice [40].

Additionally, this study proposes that employee workplace status moderates this link. This study suggests workplace status, or employees' perceived respect, prominence, and prestige within the workplace [11], [33], is a critical factor driving voice behaviour. Distinct from actual rank in the organization, workplace status is informally perceived social rank based on peer assessments [11], [39]. Lower workplace status employees perceive greater risks in speaking up because of their reduced political influence and opportunities to learn the norms of voice [32], [10].

In these circumstances, leader voice endorsement transparency is crucial. Openness helps to eliminate doubt and to increase employees' belief in their ability to provide valuable ideas and their confidence that they will be valued. This is consistent with the notion of voice efficacy, adapted from Bandura [1], i.e., the belief that one can successfully voice constructive ideas. As a result, leaders' communication of transparency in endorsing employee voice behaviour is expected to have a stronger positive effect on employee voice behaviour among employees at lower workplace status.

In line with these considerations, this study seeks to examine the influence of leader voice endorsement transparency on employee voice behaviour in the Sri Lankan IT industry, focusing on the moderating role of employee workplace status. In doing so, this study adds to the literature by extending Social Exchange Theory and emphasizing the role of leadership transparency in enhancing communication, inclusion, and innovation in organizations.

The following research questions will guide this research: What is the impact of transparency in leader voice endorsement on employee voice behaviour within the Sri Lankan IT sector? Does the employee workplace status moderate the relationship between leader voice endorsement transparency and employee voice behaviour? Consistent with these questions, the main objective of the research is to examine the impact of leader voice endorsement transparency on employee voice behaviour within the IT sector in Sri Lanka, with further emphasis on how the moderating factor is employee workplace status in Sri Lanka. In particular, the research will focus on examining the following relationship between leader voice endorsement transparency and employee voice behaviour: the moderating role of the employee's workplace status at the workplace in their relationship between leader voice endorsement transparency and employee voice behaviour. Additionally, the research aims to contribute to the development of Social Exchange Theory by pointing out the importance of transparent leadership practices in promoting mutual communication behaviours in organizations.

2 THEORY AND HYPOTHESES

2.1 *Leader voice endorsement transparency and employee voice behavior*

It is increasingly being recognized that Leader voice endorsement transparency is a significant leadership practice that determines employee voice behaviour, especially within knowledge-intensive sectors, like the

Sri Lankan IT sector. The concept of employee voice behaviour can be explained as discretionary sharing of ideas, suggestions, or concerns to enhance the effectiveness of the organization [30]. Although vital, in the case of uncertainty as to how the input will be measured, employees usually stay quiet as to whether the input will be measured fairly [9].

Using the Social Exchange Theory, workplace relationships are founded on reciprocity, where employees reciprocate positive attitudes and behaviour of the leader with positive responses [3]. In this regard, the transparency of the leader's voice may be theorized as a kind of supportive and unbiased treatment, a signal of respect, trust, and acknowledgment of employees' input.

To begin with, clear communication about the decisions on endorsements augurs more procedures with perceived fairness and organizational backing. Voice processes can be defined as being subjective in assessment and asymmetrical in terms of information between leaders and employees [13], [37]. By making it clear to the leaders how suggestions are evaluated and why specific ideas are supported, leaders decrease the uncertainties and enhance perceived equity. Previous studies indicate that fairness perceptions are the key determinants of favorable employee behaviours, and voice is one of them [8]. Such fair treatment, as suggested by Social Exchange Theory, enhances the social exchange relations, which motivates employees to reciprocate in positive ways, such as voice.

Second, the attitude of transparency associated with the leader's voice encourages trust because it explains the justification behind the decision-making procedures. Nepotism, prejudice, and favoritism among the employees can be reduced when they learn why their ideas can or cannot be implemented. One of the key processes in Social Exchange Theory is trust, as it underpins two-way relationships between leaders and employees [35], [36]. Empirical studies indicate that follower trust in their leaders leads to increased discretionary behaviours, such as employees speaking up, presenting ideas, and expressing concerns [33]. Therefore, transparency enhances trust, and this enhances employee voice behaviour.

Third, transparency in endorsement of voice by leaders is an indication of relational investment by leaders, indicating that employees are treasured members of the organization. This impression increases the feeling of duty and emotional attachment of employees to the company. According to Social Exchange Theory, when workers feel that there is a lot of organizational support, they feel obliged to reward the investment by acting in ways that are advantageous to the organization [14]. Employee voice behaviour may thus be interpreted as a positive reciprocity behaviour whereby employees will present ideas and suggestions in exchange for sustaining positive and transparent leadership behaviours.

Also, according to previous studies, the behaviours of leaders suggesting openness and support are crucial in facilitating voice behaviour [9], [30]. The transparency of endorsement processes by the leaders minimizes the perceived risk of speaking up, and they are able to provide a psychologically safe situation to the employees to share their opinions.

Leader voice endorsement transparency gains importance in the Sri Lankan IT sector, where innovation, knowledge sharing, and continuous improvement are essential for the success of the organization. Likely, when their ideas are viewed as being a real concern and fairly judged, employees would tend to voice their ideas as a way of reciprocating the favourable leadership treatment.

In general, the endorsement of leader voice transparency enhances the social exchange relationships through fairness, trust, and perceived organizational support. All these are reasons why the employees would look forward to giving back by improving employee voice behaviour.

Thus, we propose that:

H1: Leader voice endorsement transparency is positively associated with employee voice behaviour among employees in the Sri Lankan Information Technology (IT) sector.

2.2 *Moderating Role of Employee Workplace Status*

Workplace status refers to an employee's perceived respect, prestige, and standing within the workplace and is conceptually distinct from formal organizational rank [12]. Prior research shows that status-related perceptions can be associated with meaningful workplace outcomes, including how employees are evaluated and how they participate in social and organizational interactions

[5], [12], [16], [19]. Research on employee voice also indicates that employees' perceptions of interpersonal risk, authority, responsiveness, and their own standing can shape their willingness to speak up [9], [10], [17], [30].

These arguments provide a theoretical basis for examining workplace status as a possible boundary condition. Employees with lower perceived workplace status may face greater uncertainty about whether their suggestions will be taken seriously and may therefore be more attentive to explicit cues concerning how leaders evaluate voice. Conversely, employees with higher perceived status may have access to other relational or informational resources that reduce their reliance on formal guidance. More recently, Ji et al. [18] similarly theorized that leader voice endorsement transparency may be especially consequential for employees with lower workplace status because such employees can rely more heavily on explicit leader guidance when deciding whether to speak up.

Accordingly, the present study tests, rather than assumes, whether workplace status changes the strength of the relationship between leader voice endorsement transparency and employee voice behaviour in the Sri Lankan IT sector. Because the proposed differential effect requires evidence from a statistically significant interaction, the hypothesis is evaluated solely on the significance of the interaction term

Thus, we propose that:

H2: Employee workplace status moderates the relationship between leader voice endorsement transparency and employee voice behaviour among employees in the Sri Lankan IT sector, such that the relationship is stronger when employee workplace status is low rather than high.

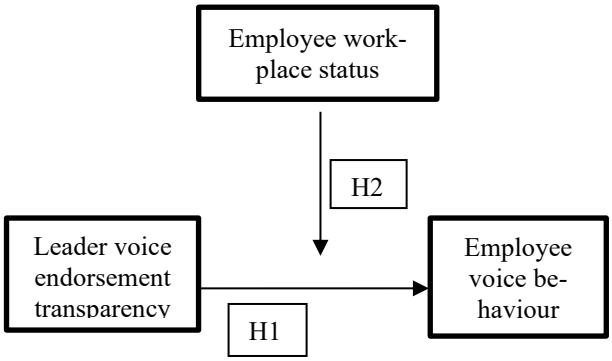


Figure 1. Hypothetical research model (source: Authors' compilation)

3 METHODOLOGY

The IT industry in Sri Lanka, one of the country's most dynamic sectors, is a relevant environment to assess employee voice behaviours [27]. Given the global competition, technological change, and innovation in IT firms, employee voice behaviour is crucial in this sector [40]. But factors such as workload, time constraints, and fast-paced work environments can affect employee voice behaviour; hence, effective leader communication is crucial [15].

This research takes a quantitative approach [20] to examine how leader endurance endorsement transparency influences employee voice behaviour, with employee workplace status as the moderator. A sample of Sri Lankan IT company employees was used.

The respondents were accessed using a convenience sampling technique, whereby the researchers used their networks to reach out to them. A non-probability sampling technique was chosen because it was practical and effective to reach those subjects who were readily available and who consented to take part, especially when time and resources were limited [38]. Despite the drawback of convenience sampling in generalizability, it has found extensive application in organizational studies where there is no easy access to the entire population. To achieve sufficient exposure to organizational practices and leadership behaviours, employees who had six months of experience in the IT sector were chosen as a study criterion. The survey used 235 responses (out of 400 questionnaires distributed) for data analysis, with an acceptable response rate.

The respondents' profile is consistent with the Sri Lankan IT industry workforce.

The participants were 57% males and 43% females, showing a somewhat equal gender representation. The largest proportion of participants was between the ages of 25 - 34, reflecting the youthfulness and dynamism of the industry. When it came to education, the majority of respondents held bachelor's degrees, with a sizeable number of respondents holding postgraduate degrees and certifications.

In terms of professional experience, most respondents possessed between 3 - 6 years of industry experience, followed by those with over 7 years, which indicates participants had sufficient experience in the intricacies of industry practices and leadership. Regarding job roles, participants held diverse positions across organizational levels: executives, middle managers, and senior managers/project managers, which provided varied information on the perceptions of leader transparency and employee voice behaviour.

The researcher used SPSS to analyze the data, which included descriptive statistics, Pearson correlation, and regression analysis to investigate the relationships in the data. Moreover, moderation analysis was conducted to examine the moderating effect of employee workplace status on the link between leader voice endorsement transparency and employee voice behaviour.

3.1 *Measures*

The instruments used in the study were in English since English is considered to be the predominant language at work in the Sri Lankan IT industry. Our questionnaire comprised scales adapted from previous research for accuracy and reliability.

3.1.1 *Leader Voice Endorsement Transparency*

Leader voice endorsement transparency was assessed using the six-item scale adapted from Ji et al. [18]. The measure assesses the extent to which leaders communicate the criteria, procedures, and reasoning used to evaluate and endorse employee suggestions. An example item is: "My supervisor adequately explains how to evaluate and endorse employee suggestions." Responses were recorded on a seven-point Likert scale ranging from 1 = strongly disagree to 7 = strongly agree. The scale demonstrated high internal consistency in the present study, with a Cronbach's alpha of 0.91. Higher scores indicate greater perceived transparency in the leader voice endorsement process.

3.1.2 *Employee Voice Behaviour*

Employee voice behaviour was assessed by using the well-known and validated 6-item scale designed by Van Dyne and LePine [22]. This measures the extent to which employees actively share ideas, suggestions, and concerns at work. A typical item is: "I generate and recommend actions dealing with issues regarding my work". Items were rated on a 7-point scale (1 = never, 7 = always). It had high reliability (Cronbach's α = .90 or higher).

3.1.3 *Employee Workplace Status*

To measure employee workplace status, we adapted a 5-item scale from Djurdjevic et al. [12] that reflects individuals' status, prestige, and reputation in the workplace. The scale includes items such as: "I have a high level of respect and recognition in my organization." The scale was measured using a 7-point Likert scale (1 = strongly disagree to 7 = strongly agree). The Cronbach's α value was .85 or higher.

3.1.4 *Data Reliability and Validity*

The measures were adapted from established literature, supporting content validity. Internal consistency was assessed using Cronbach's alpha. All reported coefficients exceeded .70, indicating acceptable to high internal consistency. The study did not report factor analysis or other construct-validity tests; therefore, the manuscript does not claim additional forms of validity beyond the use of established measures and the reported reliability evidence.

4 PRELIMINARY ANALYSIS

4.1 *Reliability test*

Table 1. Reliability analysis (Cronbach's alpha)

Variable	No. of Items	Cronbach's Alpha
Leader Voice Endorsement Transparency	6	0.91
Employee Voice Behaviour	6	0.90
Employee Workplace Status	5	0.85

(Source: SPSS Output)

All variables exceeded the recommended threshold of 0.70, indicating high internal consistency and reliability.

4.2 *Correlation Analysis*

Table 2. Correlation analysis (Pearson correlation)

Variables	Leader voice endorsement transparency	Employee Voice Behaviour	Employee Workplace Status
Leader voice endorsement transparency	1		
Employee Voice Behaviour	0.61**	1	
Employee Workplace Status	0.28**	0.35**	1

** $p < 0.01$

(Source: SPSS Output)

There is a strong positive relationship between leader voice endorsement transparency and employee voice behaviour ($r = 0.61$, $p < 0.01$), supporting initial expectations.

4.3 *Regression Analysis*

Table 3. Model summary

R	R^2	Adjusted R^2	Std. Error
0.61	0.37	0.36	0.52

(Source: SPSS Output)

4.4 *ANOVA Test*

Table 4. ANOVA table

Source	Sum of Squares	df	Mean Square	F	Sig.
Regression	45.21	1	45.21	167.85	0.000
Residual	76.35	233	0.33		
Total	121.56	234			

(Source: SPSS Output)

Table 5. Coefficients table

Variable	B	Std. Error	Beta (β)	t	Sig.
(Constant)	1.25	0.21	-	5.95	0.000
Leader-voice endorsement transparency	0.55	0.04	0.55	12.96	0.000

(Source: SPSS Output)

Leader voice endorsement transparency has a statistically significant positive effect on employee voice behaviour ($B = .55$, $\beta = .55$, $p < .001$). Therefore, H1 is supported.

4.5 *Moderation Analysis (Interaction Effect)*

Table 6. Model summary (moderation model)

R	R^2	Adjusted R^2
0.63	0.40	0.38

(Source: SPSS Output)

Table 7. Coefficients table (moderation model)

Variable	B	Std. Error	Beta (β)	t	Sig.
(Constant)	1.18	0.22	-	5.36	0.000
Leader voice endorsement transparency	0.52	0.05	0.52	10.40	0.000
Workplace Status	0.21	0.06	0.18	3.50	0.001
Leader voice endorsement transparency × Workplace Status (Interaction Term)	-0.06	0.04	-0.07	-1.65	0.100

(Source: SPSS Output)

The interaction term is negative but not statistically significant ($B = -.06$, $\beta = -.07$, $t = -1.65$, $p = .100$). Accordingly, there is insufficient statistical evidence that employee workplace status changes the strength of the relationship between leader voice endorsement transparency and employee voice behaviour. The negative sign may be reported descriptively, but it must not be interpreted as evidence of a stronger relationship at low workplace status or a weaker relationship at high workplace status. Therefore, H2 is not supported.

5 DISCUSSION

The study examined the relationship between leader voice endorsement transparency and employee voice behaviour and tested whether employee workplace status moderated this relationship in the Sri Lankan IT sector. The results provide clear support for the direct relationship but do not provide statistical support for the proposed moderation.

First, leader voice endorsement transparency was strongly and positively associated

with employee voice behaviour ($r = .61$, $p < .01$), and it remained a significant positive predictor in the regression model ($B = .55$, $\beta = .55$, $p < .001$). This finding is consistent with the broader employee voice literature showing that leadership behaviours and contextual signals influence whether employees consider speaking up worthwhile and safe [9], [30], [31]. It is also directly consistent with Ji et al. [18], who found that greater transparency regarding the criteria used to endorse employee suggestions was associated with greater employee voice. In the present study, the finding suggests that when leaders explain how suggestions are assessed and why ideas are accepted or not accepted, employees are more likely to contribute work-related ideas, concerns, and suggestions.

From a Social Exchange Theory perspective, transparent communication can be understood as a positive relational signal that communicates respect, procedural clarity, and attention to employees' contributions [3], [8]. Employees may reciprocate such treatment through constructive discretionary behaviour, including voice. However, because the study is cross-sectional, this interpretation should be presented as a theoretical explanation of the observed association rather than as proof of a causal exchange process.

Second, the regression model explained approximately 37% of the variance in employee voice behaviour ($R^2 = .37$), and the overall model was statistically significant ($F = 167.85$, $p < .001$). These findings indicate that leader voice endorsement transparency is an important predictor within the present sample. Nevertheless, the unexplained variance also indicates that other factors identified in the voice literature, such as psychological safety, leader openness, trust, perceived efficacy, and organizational context, may additionally shape employee voice [9], [10], [30], [31].

Third, the proposed moderating role of employee workplace status was not supported. Although workplace status had a significant positive main effect in the moderation model ($B = .21$, $\beta = .18$, $p < .001$), the interaction between workplace status and leader voice endorsement transparency was not statistically significant ($B = -.06$, $\beta = -.07$, $p = .100$). The correct conclusion is therefore that the present data do not demonstrate that workplace status changes the strength of the relationship between leader voice endorsement transparency and employee voice behaviour.

The negative interaction coefficient should not be described as partial support, directional support, weak moderation, or restrained but significant moderation. A coefficient in the hypothesized direction without statistical significance does not establish the proposed interaction. The result may instead be discussed as a theoretically interesting but unsupported pattern that warrants replication with adequate statistical power and, ideally, designs that reduce common-method and cross-sectional limitations.

This non-significant result is informative because prior research does not require every plausible contextual factor to moderate in every organizational setting. Workplace status is a meaningful construct in organizations [12], and status-related processes have been linked with voice and supervisory responsiveness [17]. However, the present Sri Lankan IT sample did not provide evidence that status altered the effect of leader voice endorsement transparency. One possible explanation is that other contextual mechanisms may be more proximal to employees' decisions to speak up, such as voice efficacy, psychological safety, leader responsiveness, or trust. This is an inference for future research rather than an empirical explanation established by the current data.

Overall, the findings support transparent leader communication as a significant predictor of employee voice behaviour. They also show that workplace status is positively associated with voice in the model but is not established as a boundary condition for the transparency-voice relationship in this study. This distinction between a significant main effect and a non-significant interaction is essential to the interpretation of the results.

6 THEORETICAL IMPLICATIONS

The primary theoretical contribution of this study lies in extending the empirical examination of leader voice endorsement transparency to the Sri Lankan IT context. The results support the proposition that transparency about how employee suggestions are evaluated is positively associated with subsequent employee voice. This complements the broader voice literature, which emphasizes the importance of contextual

and leadership signals in shaping employees' decisions to speak up [9], [30], [31], and is directly aligned with the recent conceptualization and evidence reported by Ji et al. [18].

The study also contributes by distinguishing between what is theoretically proposed and what is empirically demonstrated. Workplace status was tested as a moderator because status-related perceptions can shape organizational interactions and voice-related processes [12], [17]. However, the non-significant interaction means that the study does not extend theory by establishing workplace status as a boundary condition in this relationship. Instead, it provides a useful null finding: in this sample, the effect of leader voice endorsement transparency on employee voice did not significantly differ across levels of workplace status.

This result also refines the application of Social Exchange Theory. The significant direct relationship is consistent with the idea that positive and transparent treatment may be reciprocated through constructive employee behaviour. However, the study does not provide direct evidence that workplace status systematically changes this exchange process. Future studies should test the underlying mechanisms more directly, for example by examining voice efficacy, trust, perceived procedural fairness, or psychological safety as mediating processes and by assessing theoretically grounded moderators with stronger design-based evidence.

Accordingly, the theoretical implication is not that workplace status weakly or directionally moderates the relationship, but that the proposed status-based boundary condition was not demonstrated in the present data. Reporting this result accurately strengthens the credibility of the study and provides a clearer basis for future research.

7 PRACTICAL IMPLICATIONS

The findings provide several practical implications for managers and organizations in the Sri Lankan IT industry. Because leader voice endorsement transparency was a significant positive predictor of employee voice behaviour, managers should clearly communicate how employee suggestions are evaluated, what criteria are used when deciding whether an idea can be adopted, and why particular suggestions are accepted, modified, deferred, or rejected. Such communication can reduce ambiguity and provide employees with clearer information about how to participate constructively.

Organizations should also establish consistent feedback practices. Formal idea-submission channels, transparent evaluation criteria, documented response processes, and timely feedback can help ensure that employees understand what happens after they speak up. These practices are consistent with the broader literature emphasizing the importance of contextual signals and leader responses in sustaining employee voice [9], [30], [31].

The practical recommendations should not claim that low-status employees benefit more from transparency, because the moderation hypothesis was not supported. Instead, organizations should apply transparent and respectful voice processes across employees regardless of perceived workplace status. Status differences may still be relevant to inclusion and participation, but this study does not provide statistical evidence that status changes the effectiveness of leader voice endorsement transparency.

Leadership development programmes may therefore focus on explaining evaluation criteria, listening to employee input, providing specific reasons for decisions, and responding consistently to both accepted and rejected suggestions. The aim should be to create a reliable voice process rather than to target a particular status group on the basis of an unsupported interaction.

8 LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

These research findings are influential to the areas of interest, and they make an indelible mark on the transparency of leader voice endorsement and its effects on employee voice behaviour in the Sri Lankan IT industry. Nevertheless, there are a number of limitations to the interpretation of the results.

To begin with, the research was based on self-administered questions gathered via questionnaires, which could have led to the emergence of common method bias (CMB) and bias associated with responses (social desirability and consistency effects) [20], [36]. Even though the self-report scale is suitable due to the perceptual quality of such

constructs as voice behaviour and workplace status, in future research, multi-source data might prove to be more effective in adding strength to the results, e.g., supervisor ratings, peer ratings, etc.

Secondly, a cross-sectional research design does not allow for determining the causal relationship between leader transparency and employee voice behaviour. Although the analysis of correlation and regression has found significant levels of association, they do not establish directionality. There is a need for longitudinal designs or time-lag designs to develop causal dynamic relations and changes over time in the future [34]. Strengthening causal inference could be accomplished through experimental methods as well.

Thirdly, the research was carried out using convenience sampling and based on employees of a few IT firms in Sri Lanka. This can restrict its ability to generalize the results to the larger IT industry or other industries. Further research needs to employ probability sampling methods and use a larger sample, with variation in organizational sizes, geographical location, and industries, to enhance the external validity.

Fourthly, the moderating position of employee workplace status was investigated in this study, but with a weak and statistically insignificant moderation effect. This implies that other contextual or psychological issues could be having a greater role to play. The subsequent studies are to investigate further moderators (psychological safety, leadership style (e.g., transformational or inclusive leadership), organizational culture, trust in leadership, and emotional intelligence), which will give deeper responses on the question of when and how often leader transparency can affect voice behaviour. Future studies could also examine additional potential moderating variables, such as voice efficacy, leader-member exchange, and perceived organisational support. These variables may provide further insight into the conditions under which leader voice endorsement transparency is more likely to encourage employee voice behaviour.

Lastly, this paper is rooted in Social Exchange Theory, which deals mostly with reciprocal interactions between leaders and employees. Informational theoretical approaches like Social Identity Theory or Conservation of Resources Theory may be incorporated in future studies so as to have an overall interpretation of employee voice behaviour. Also, qualitative methods (e.g., interviews or focus groups) may help to reveal subtle details of how employees may view leader transparency in the context of actual organizations.

To sum up, although this paper has added to the body of knowledge by emphasizing the role of transparent leadership in stimulating employee voice in the Sri Lankan IT industry, the study in the future studies in response to these shortcomings will build the theoretical bases and practical implications.

9 CONCLUSION

This study concludes that leader voice endorsement transparency is positively associated with employee voice behaviour in the Sri Lankan IT sector. The findings support the view that clear and transparent communication about how employee suggestions are considered can encourage employees to express their ideas and concerns. However, the study did not find evidence that employee workplace status significantly changes this relationship. Overall, the findings highlight the importance of transparent leadership practices in encouraging employee voice while suggesting that other contextual factors may better explain differences in voice behaviour.

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Rights of Songwriters V. Digital Intermediaries: A Critical Analysis of the EU Copyright Regime

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ABSTRACT: Concerns regarding the effectiveness of copyright standards in ensuring whether songwriters receive fair remuneration have been raised by the rapid development of digital music streaming services, which has completely changed the music industry's structure. This study looks at how well the legal system in the European Union achieves a balance between the rights of traditional composers and the interests of digital intermediaries. It focuses on whether structural imbalances in the digital music industry are adequately addressed by current legal procedures. This study adopts a legal approach to support its qualitative doctrinal methodology. It examines regulations, legislation, and scholarly writings about digital music distribution and copyright. The EU Directive on Copyright in the Digital Single Market is an important piece of legislation used. The findings demonstrate that the European Union framework takes an interventionist stance, putting in place procedures meant to improve justice and provide more equitable remuneration. However, implementation and enforcement issues restrict the EU regime's effectiveness. The analysis comes to the conclusion that the EU framework does not offer a complete solution. Even if the model is more advanced, fundamental issues in digital markets continue to limit the system, emphasizing the necessity for broader regulatory inter-vention.

Keywords: copyright law, songwriter remuneration, digital intermediaries, music streaming, EU Digital Single Market Directive

1 INTRODUCTION

Music production, distribution, and revenue generation have all seen significant changes as a result of the music industry's rapid digitization. With the shift from digital downloads and physical formats to streaming-based consumption patterns, digital platforms are now the main gatekeepers of music access. Today, streaming services like Spotify, Apple Music, and YouTube control the majority of the world's music distribution, changing the industry's economic structure as well as the legal dynamics between creators and intermediaries. The global reach and accessibility have been improved by this shift, but the power balances within the copyright ecosystem have undergone modifications as well. The songwriter, who is recognized as the author of the musical composition under copyright law, is at the center of the music industry. Authors have traditionally been granted exclusive economic rights under copyright protection, including the ability to reproduce, distribute, and communicate with the public. The idea behind copyright law is that authors can control how their works are exploited and receive remuneration that is appropriate for their original contribution by virtue of exclusive rights.

However, there are several obstacles in the way these rights' practical application in the contemporary digital environment. It is rare for songwriters to directly exploit their rights. Rather, their works are licensed and

managed by complex networks of intermediaries, such as digital platforms, publishers, and collective management organizations. The emergence of streaming has made this intermediation more intense. Streaming platforms, in contrast to traditional distribution models, use algorithm-driven systems to figure out revenue distribution, market reach, and visibility. Consequently, the process of determining and allocating royalties has grown more complex and occasionally opaque Concerns have been expressed about whether the current legal frameworks are sufficient to protect songwriters' economic interests in light of this structural change. The Directive (EU) 2019/790 on Copyright in the Digital Single Market (DSM Directive) represents an interventionist regulatory approach by the European Union. In order to increase author protection, the Directive includes clear provisions pertaining to contractual adjustment methods, fair and adequate remuneration, and transparency. These actions acknowledge that in order to address the structural disparities between creators and intermediaries, digital markets may need legislative safeguards. The legal status of songwriters in the digital music sector is a crucial contemporary concern. The practical enjoyment of copyright has changed as a result of the development of digital intermediaries, raising questions about whether the proper balance between commercial interests and creative rights are still in place.

Although songwriters are officially recognized by copyright law as authors and primary rights holders in musical compositions, it is becoming more unclear whether this recognition translates into significant economic protection in the digital music industry. The main concern is not whether exclusive rights exist, but instead whether the legal framework governing their practical exploitation in platform-dominated marketplaces is adequate. Streaming platforms have significant influence over market visibility, revenue distribution methods, and licensing terms. Songwriters' ability to determine whether remuneration fairly represents the commercial exploitation of their works is hampered by the complexity and lack of transparency of royalty regimes. The idea that private negotiation would result in just outcomes is called into doubt when a disparity in unequal bargaining power continue.

Under the Directive (EU) 2019/790 on Copyright in the Digital Single Market, the European Union established explicit statutory mechanisms to strengthen author protection through the principles of contractual adjustment rights, transparency obligations, and fair and proportionate remuneration. Legislative acknowledgment that fundamental inequalities in digital markets could require targeted intervention is reflected in these laws.

The European Union provides a particularly relevant framework for examining these issues because the DSM Directive represents a significant development in the regulation of contractual relationships between authors and their commercial counterparties in the digital environment. In contrast to copyright rules that primarily establish exclusive rights and intermediary liability, the DSM Directive introduces specific mechanisms aimed at improving authors' remuneration, access to information, and contractual protection. The EU framework therefore provides a useful legal context for assessing whether copyright intervention can address the structural imbalance between songwriters and digital intermediaries while maintaining the interests of digital platforms and other market participants.

In light of the changing digital music industry and current copyright legislation, this study is academically significant. The economic environment in which musical compositions are exploited has drastically changed due to the quick growth of digital streaming, which raises serious concerns about the continued efficacy of traditional copyright frameworks in protecting authors. From an academic standpoint, this study adds to the corpus of literature by offering a focused review of songwriter remuneration in the digital sphere. While copyright law, digital platforms, and the economics of streaming have all been thoroughly studied in previous research, the unique legal context of songwriters as opposed to performers and record producers has received relatively limited attention. This work fills an identified gap in legal literature by taking a songwriter centric approach and provides a deeper knowledge of how copyright law functions in practice despite complex intermediary structures.

Against this background, this study critically examines whether the EU copyright framework provides an effective legal re-

sponse to the challenges faced by songwriters in the digital music industry. Particular attention is given to the relationship between copyright protection, digital intermediary liability, transparency, contractual adjustment, and remuneration. The study argues that although the EU framework represents a significant movement towards stronger author protection, its effectiveness remains constrained by enforcement difficulties and broader structural features of the digital music mar-ket.

2 LITERATURE REVIEW

The legal, economic, and structural dynamics controlling the production, distribution, and monetization of musical compositions have been drastically changed by the music industry's rapid digital revolution. In addition to improving accessibility, the shift from physical sales and digital downloads to streaming-based consumption models has altered the industry's power dynamics. A crucial conflict between songwriters, who are the primary creators of musical works, and digital intermediaries, who now control access to audiences and income sources, is at the center of this transformation. By giving writers exclusive economic rights, such as the ability to reproduce, distribute, and communicate with the public, copyright law has historically aimed to reward creative labor. Theoretically, these rights give songwriters the ability to manage how their works are exploited and obtain fair remuneration. However, in the digital age, where exploitation is mediated through several tiers of intermediaries, such as publishers, digital streaming platforms, and collective management organizations (CMOs), the practical implementation of these rights becomes increasingly complex. Academic research frequently emphasizes how digital platforms like Spotify, Apple Music, and YouTube have developed into strong gatekeepers that manage licensing arrangements, data transparency, and revenue allocation methods. This change has sparked significant concerns about information asymmetry, unequal bargaining power, and opaque royalty schemes, all of which compromise copyright law's ability to fairly remunerate songwriters. With Directive (EU) 2019/790 on Copyright in the Digital Single Market (DSM Directive) the European Union has taken a more interventionist and author-centric stance, adding clear clauses on equitable remuneration transparency, and contractual alterations. The body of scholarly research, case law, and policy documents pertaining to songwriter remuneration and digital intermediaries is critically examined.

2.1 *Digital Intermediaries and the Transformation of Music Licensing*

The music industry's structure has undergone a fundamental transformation due to the rise of digital streaming platforms. In modern times, platforms including YouTube and Spotify serve as powerful intermediaries, influencing revenue distribution and audience access. According to scholarly arguments, these platforms operate as gatekeepers, controlling market entry, visibility, and revenue. The financial success of musical works is directly impacted by digital platforms, which, in contrast to traditional intermediaries, rely on algorithmic methods to curate content and distribute exposure. The increase of exclusive rights in reaction to technical advancement is highlighted in the literature on digital copyright. The Information Society Directive 2001/29/EC is often cited as a vital instrument in this process, especially because it harmonizes the public's right to communication. Scholars contend that although these rights control access to works, they do not deal with how economic value is distributed in online marketplaces. For songwriters, this concentration of power has significant implications. According to the studies, the transition from ownership-based to access-based streaming models has decreased income per unit while increasing reliance on platform ecosystems. As a result of this, songwriters frequently receive profits that are disproportionately low. Intermediary liability regimes have a significant impact on the overall regulatory environment although they are mostly focused on copyright infringement. The legal rules defining platform duty are demonstrated by cases notably Google France v Louis Vuitton and Football Association Premier League v QC Leisure. According to academics, limited liability frameworks may unintentionally weaken the platforms' incentives to use fair licensing procedures. These frameworks enable platforms to hold dominating positions without

adequate requirements to guarantee equitable remuneration by reducing legal risk.

2.1.1 *Intermediary Liability and Regulatory Im-plications*

Intermediary liability regimes have a significant impact on the overall regulatory environment although they are mostly focused on copyright infringement. The legal rules defining platform duty are demonstrated by cases notably Google France v Louis Vuitton and Football Association Premier League v QC Leisure. According to academic discussions, limited liability frameworks may unintentionally weaken the platforms' incentives to use fair licensing procedures. These frameworks enable platforms to hold dominant positions without adequate requirements to guarantee equitable remuneration by reducing legal risk.

However, the literature also indicates that intermediary liability and songwriter remuneration are related but distinct legal issues. Traditional intermediary liability rules primarily concern whether and under what circumstances platforms may be held responsible for infringing content, whereas the economic position of songwriters concerns the distribution of value generated through the lawful exploitation of their works. Consequently, stronger intermediary liability does not automatically result in fairer remuneration for individual authors. This distinction is significant because a platform may satisfy its copyright obligations while songwriters continue to face limited information about the commercial exploitation of their works or unequal bargaining positions when negotiating licensing arrangements. The literature therefore suggests that regulating intermediary liability alone cannot fully address the economic relationship between creators and digital platforms.

The development of the DSM Directive reflects this limitation by moving beyond the traditional focus on infringement and introducing provisions aimed at improving authors' contractual and economic position. This represents an important shift in the literature and regulatory debate: the question is no longer limited to whether digital intermediaries should be liable for copyright infringement, but also whether the legal framework should intervene in the contractual and informational relationships through which authors receive remuneration. Nevertheless, the effectiveness of such intervention remains dependent on implementation, enforcement, and the ability of individual authors to exercise the rights provided by the legislation. This creates a continuing gap between the formal recognition of author protection and its practical effect within the platform-based music industry.

2.2 *EU Copyright Framework and the DSM Di-rective*

A major step toward a more interventionist and author-focused copyright policy was made with the approval of the DSM Directive. Concerns about systemic underpayment are explicitly addressed by Article 18, which defines the idea that authors are entitled to "appropriate and proportionate remuneration." Additional protections, that includes an amendment to the contract process and transparency obligations, are introduced in Articles 19 and 20. By addressing information asymmetry, these clauses guarantee that authors can renegotiate contracts in cases when remuneration turns out to be disproportionately low. Principles already acknowledged in CJEU case law are reflected in this development.

The Court emphasized in Luksan v Van der Let that authors must maintain their effective right to remuneration even in cases where contractual agreements are in place. This has been seen by academics as proof of an overall shift in EU copyright law toward an author-protective stance. Many academics consider these actions to be a break from conventional contract-based models. The Directive aims to re-balance the relationship between creators and intermediaries by incorporating mandatory protections into the legal framework. However, there are issues with fragmentation and inconsistency because the effectiveness of these laws depends on how they are implemented at the national level.

Though not without criticism, academic responses on the DSM Directive generally is supportive. Senftleben describes the Directive as a paradigm change that incorporates equity into copyright agreements. In a similar vein, Geiger highlights how the EU legislative system strengthens author protection. However, academics like Dusollier warn that the Directive's efficacy depends on how it is actually implemented, pointing out potential challenges with compliance and enforcement. Derclaye argues that man-

dated protections are required to reduce structural inequalities, highlighting the conflict between contractual freedom and statutory intervention. These perspectives are supported by policy materials. The European Parliament Research Service draws attention to the economic imbalance between platforms and creators, while the European Commission's Impact Assessment identifies underpayment and a lack of transparency as key factors influencing reform.

3 METHODOLOGY

This study adopts a qualitative doctrinal methodology to examine how effectively the European Union copyright framework balances the rights of songwriters against the interests of digital intermediaries. The doctrinal approach involves a systematic analysis and interpretation of primary and secondary legal sources. Primary sources include relevant EU legislation, particularly Directive (EU) 2019/790 on copyright and related rights in the Digital Single Market (DSM Directive), together with relevant decisions of the Court of Justice of the European Union (CJEU) interpreting copyright principles. Secondary sources include academic literature, legal commentaries, policy reports, and industry publications, which are critically examined to identify differing scholarly perspectives and assess the practical effectiveness of the legal framework. The DSM Directive is selected as the principal legislative framework because it introduced specific mechanisms concerning authors' remuneration, transparency, contractual adjustment, and the regulation of certain digital intermediary activities. The EU is therefore used as the principal jurisdiction focus to assess whether an interventionist copyright framework can address structural issues such as information asymmetry, unequal bargaining power, and the potential imbalance between creators and digital platforms. Particular attention is given to the extent to which transparency and contractual protections can improve the position of songwriters within the digital music market. The study does not employ interviews, surveys, or quantitative data; instead, its conclusions are developed through the interpretation and critical evaluation of legal and documentary materials. Accordingly, the methodology combines doctrinal legal analysis with a critical evaluative approach to determine whether the existing EU copyright framework provides an effective legal response to the challenges faced by songwriters in the digital environment.

4 ANALYSIS

4.1 *The EU Directive: Regulatory Innovation or Partial Solution?*

A significant shift from a purely market-based approach to copyright regulation is represented by the European Union's approval of the DSM Directive, which reflects an increasing recognition that contractual autonomy alone is insufficient to guarantee songwriters' fair remuneration in the digital sphere. The DSM Directive introduces substantive measures intended at improving the financial position of authors, including songwriters, in contrast to previous instruments like the Information Society Directive 2001/29/EC, which primarily focused on harmonizing exclusive rights. However, given the structural realities of platform-driven markets, the Directive's effectiveness must be critically assessed even though it adds significant procedures intended to rebalance relationships within the music industry. Article 17 imposes direct liability on online content-sharing service providers for user-uploaded unauthorized copyrighted content, reflecting a major shift in the regulation of digital intermediaries.

The provision recognizes platforms' active role in distributing works to the public and requires them to obtain licenses from rightsholders or show "best efforts" to prevent the release of infringing content. This is a shift from the traditional intermediary liability regime, which treated platforms as passive hosts. This change is strongly related to the "value gap" debate, which draws attention to the difference between the substantial revenue made by digital platforms and the relatively limited remuneration that artists and songwriters receive.

However, as recognized in Poland v. Parliament and Council, the duty to prevent the availability of infringing content has been widely interpreted as requiring automated content filtering technologies, raising concerns about over-blocking and the restriction of legitimate uses like parody and quotation. Therefore, even if Article 17 is a more interventionist and economically responsive ap-

proach, it also shows that attempts to bridge the value gap may lead to new conflicts between fundamental rights and copyright enforcement. The issues brought up before the Belgian Constitutional Court regarding Article 17 further highlight the conflicts present in the EU's platform-based regulation paradigm. The referral questioned whether imposing direct liability on online content-sharing service providers would actually require the use of automated content filtering mechanisms, potentially interfering with users' fundamental rights, especially the EU Charter's guarantee of freedom of expression. This draws attention to a crucial flaw in the EU's strategy: while Article 17 aims to restore balance between digital intermediaries and rightsholders by integrating enforcement requirements into platform architecture, it also transfers significant regulatory authority to private entities running algorithmic control systems.

Article 18, which states that authors are entitled to "appropriate and proportionate remuneration" for the exploitation of their works, is the cornerstone of this framework. This clause represents a significant shift from the tradition of depending on contractual autonomy. Article 18 recognizes that in markets with structural inequality and power concentration, the UK framework's assumption that freely negotiated agreements will result in fair outcomes is unacceptable. This clause establishes a normative framework by which remuneration can be evaluated in the context of the digital music industry, where songwriters frequently have less bargaining power than publishers, record labels, and digital platforms. As a result, it reinterprets copyright as a means of guaranteeing fairness in distribution rather than merely a system of exclusive rights. However, the availability of information has an inherent relationship to Article 18's effectiveness.

Authors are unable to determine if remuneration is "appropriate and proportionate" without access to reliable data about the exploitation and revenue generated by their works. Article 19, which requires exploiters to be transparent, addresses this issue. This provision gives authors the right to regular, up-to-date, and relevant information on how their works are exploited, including means of revenue and methods of exploitation. This is a significant development in the digital music sector, where revenue flows are frequently complicated and distributed among multiple intermediaries. It specifically addresses the issue of information asymmetry, which has long made it challenging for songwriters to evaluate or argue their remuneration.

In order to remedy this problem, exploiters are required by Article 19's transparency obligations to provide authors information about how their works are exploited and the revenue they gain. From a theoretical standpoint, this is an important advance since effective rights requires transparency. Authors are unable to assess whether they are being rewarded appropriately or confront exploitative behaviors if they lack access to information. Without transparency there’s no real ability to claim for fair remuneration. However, it is still uncertain how Article 19 will actually be implemented. The clause does not specify particular standards for the information's format, accessibility, or clarity. As a result of this, there is a chance that disclosures will be extremely technical or inadequate, which would limit their practical value. Transparency by itself might not be enough to rebalance bargaining power in extremely complex digital ecosystems unless it is combined with mechanisms that allow authors to act upon the information they receive.

Nevertheless, the practical implementation of these requirements is crucial to their efficacy. There is a chance that the information will be extremely technical, incomplete, or presented in a way that makes it challenging for authors to understand. Furthermore, minimalistic disclosure practices may result from the administrative burden of compliance, which would reduce the information's substantive value. As a result, although Article 19 theoretically tackles the issue of information asymmetry, it fails in addressing the challenges related to transparency in complex digital ecosystems. Perhaps the most practical attempt to address unfair remuneration is found in Article 20, which establishes a contract adjustment mechanism. Article 20, also referred to as the "contract adjustment" or "bestseller" provision, provides such a method.

In cases where the original agreed-upon remuneration turns out to be disproportionately low given the work's eventual success, this clause enables authors to request further remuneration. This is an essential corrective measure in the music industry, as songs may bring in substantial amounts of revenue over

a period of time, especially through streaming. It recognizes that strict adherence to initial agreements may result in unjust outcomes and that the value of creative works cannot always be predicted at the time of contracting. The Directive recognizes that contractual arrangements might not take into consideration the long-term value of creative works by permitting authors to seek additional compensation in cases where the original agreement turns out to be disproportionately low. In the context of the music industry, where works may produce significant revenue over extended periods of time, this principle is particularly significant.

Despite its potential, Article 20's efficacy is nonetheless limited by practical issues. The system depends on authors reporting claims, which could be hampered by a lack of financial constraints, lack of awareness, or concern over straining business relationships. Additionally, proving that remuneration is "disproportionately low" creates evidentiary challenges, especially in a setting where access to relevant data remains constrained. As a result, although the clause strengthens authors' legal standing, it doesn't eliminate the structural obstacles that can keep them from claiming their rights. Furthermore, it may be challenging to prove that remuneration is "disproportionately low," especially if access to relevant data is, however, restricted in spite of Article 19's transparency obligations. Through Article 17, the DSM Directive addresses the role of digital platforms in addition to contractual regulations. The DSM Directive addresses the role of digital platforms in addition to contractual regulations, primarily through Article 17.

This provision makes online content-sharing service providers, like YouTube, directly liable for public communications when they grant access to user-uploaded copyrighted content. Platforms must therefore secure licenses from rights holders and guarantee that an appropriate remuneration is paid. In contrast to a scenario where platforms could rely on intermediary liability exemptions, this signifies a substantial change in the distribution of responsibility within the digital ecosystem. In theory, Article 17 has significant impacts on songwriter remuneration since it gives rights holders more bargaining power with platforms. However, since remuneration is still mediated through contractual agreements with publishers and collecting societies, its effect on individual songwriters is usually indirect. Therefore, even though the provision deals with the interaction between platforms and rights holders, the internal revenue distribution within the music industry remains unresolved. Furthermore, the Directive's author-protective approach is further reinforced by Articles 22 and 23. A right of revocation is introduced in Article 22, enabling authors to reclaim their rights in cases when their works are not being adequately exploited. This gives songwriters some power when intermediaries fail to actively promote their compositions. Stronger parties are prevented from circumventing these provisions by Article 23, which guarantees that the measures outlined in Articles 18–22 are mandatory and cannot be waived by contract.

When considered as a whole, these provisions reflect a major shift in EU copyright law from a solely proprietary conception of copyright to a more interventionist and author-protective framework. The DSM Directive aims to address the long-standing imbalance between authors and exploiters in the digital music industry by establishing enforceable principles of fair remuneration, transparency, and contractual adjustment. By recognizing that the market cannot be relied upon to provide equitable outcomes for creators, especially in industries dominated by powerful intermediaries, it reflects a broader normative shift within EU law. However, the structural realities of the digital music ecosystem must be taken into consideration while evaluating this framework's effectiveness.

The Directive does not significantly alter the broader economic framework that governs the contractual relationships between authors and their direct counterparties, such as publishers and producers, even if it effectively intervenes at such a level. Specifically, the business models of digital platforms which are vital in determining how value is generated, distributed, and captured are not directly regulated by the Directive. For the majority of songwriters, the practical impact of statutory remuneration rights is limited because streaming services continue to rely on pro-rata payment methods that concentrate revenue among a small number of highly visible works. Furthermore, even while Articles 18–20 establish procedures meant to improve fairness, their actual effectiveness remains reliant on enforcement. In

an industry where creators may lack the financial resources, legal expertise, or bargaining confidence required to challenge established industry practices, the reliance on individual authors to invoke transparency rights or pursue contract adjustment claims creates a significant barrier. This raises questions about whether the Directive's transformative potential will be limited by its underutilization in reality, despite its progressive design.

The Directive's limited focus on data control and algorithmic governance is another negative aspect. In the world of digital music, platform-controlled algorithmic recommendation systems are rapidly influencing visibility and thus revenue. However, there are no significant requirements for algorithmic transparency or balanced exposure under the Directive. Because of this, even in cases when songwriters are granted enhanced contractual rights, their capacity to generate income is still reliant on mechanisms that fall beyond the scope of traditional copyright laws. Consequently, the DSM Directive does not fully address the issue of songwriter remuneration in the digital age, even if it is a significant and essential step towards resolving the shortcomings of previous copyright frameworks. Instead, it should be viewed as a partial and evolving intervention that essentially remains broader structural issues while addressing specific aspects of inequality, especially at the contractual level. This supports the claim that a more comprehensive regulatory strategy that addresses the technological and economic foundations of the digital music industry is necessary in addition to copyright law reform in order to achieve truly fair remuneration for songwriters.

As a result, the DSM Directive should be viewed as a significant but partial intervention. It provides techniques that improve author protection and clearly acknowledges the shortcomings of market-based approaches. However, its effectiveness is limited by challenges with implementation, enforcement, and its limited interaction with the power of digital intermediaries. This analysis suggests that while the EU framework is more advanced and a normatively responsive model, it does not provide a complete solution to the problem of songwriter remuneration in the digital music industry. Instead, it should be considered an initial step toward a more balanced regulatory framework, which needs to be accompanied by broader legal and policy interventions concerned with data asymmetries, platform governance, and the structural dynamics of digital markets.

5 CONCLUSION

This paper provides a comprehensive conclusion to the dissertation by synthesizing the findings derived from the doctrinal and comparative analysis undertaken in the proceedings. The study has examined the extent to which the legal framework of the European Union balance the rights of songwriters against those of digital intermediaries within the rapidly evolving digital music industry. The economic and legal environment of music distribution has been drastically altered by the rise of streaming services, posing difficult concerns about whether traditional copyright concepts are sufficient to guarantee fair remuneration. In this regard, the research has attempted to assess critically whether the current legislative frameworks are able to rectify the structural imbalances that define the interaction between digital intermediaries and songwriters. As a result, this paper goes beyond description to offer a concluding, well-reasoned review of the effectiveness of both legal systems. The European Union has shown a greater capacity to modify its legislative structure in response to the difficulties of digitalization. A major advancement in this area is the approval of Directive (EU) 2019/790 on Copyright in the Digital Single Market, which introduces procedures intended to improve authors' position in the digital economy. The Directive acknowledges that market forces alone are insufficient to guarantee fair outcomes, reflecting a shift towards a more interventionist and rights-based approach. The information asymmetries and power disparities that disadvantage songwriters are intended to be addressed by provisions pertaining to transparency, remuneration adjustment, and contractual fairness. These measurements show a deeper comprehension of the structural dynamics of the digital music industry. The EU framework aims to rebalance the relationship between the parties by enforcing requirements on intermediaries and strengthening the rights of authors.

Nevertheless, despite these developments, a variety of challenges continue to

limit the EU framework's effectiveness. The degree of protection provided to songwriters varies depending on how the Directive is implemented in each Member State. Furthermore, there are frequently limited enforcement mechanisms, which makes it challenging for individual authors to defend their rights against powerful intermediaries. Additionally, the Directive does not adequately address the wider economic domination of digital platforms, even though it does address certain contractual and informational issues. As a result, its ability to attain substantive fairness remains limited. In the end, this research has shown that modest changes to copyright law are insufficient to address the problem of ensuring fair remuneration for songwriters in the digital music industry. The European Union framework represents a more progressive and interventionist attempt to recalibrate the imbalance between authors and digital intermediaries. The persistence of unequal bargaining power, informational asymmetries, and concentrated economic control suggests that copyright law, in its current form, operates within limits that it cannot independently overcome. Therefore, the question is no longer whether the law recognizes the problem, but whether it is willing to evolve beyond its traditional boundaries to address it effectively. In this respect, achieving genuine fairness for songwriters requires not only legal reform, but a broader restructure of the regulatory landscape one that is capable of confronting the economic dynamics of the digital age and ensuring that creative labor is not merely protected in principle, but rewarded in practice.

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Factors Influencing Sri Lankan Millennials' Purchase Intention on Sustainable Apparel Products

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ABSTRACT: The primary goal of this research project is to find out how millennials' purchase intentions affect Sri Lankan green clothing products. The two research questions in this study are intended to help accomplish its primary goal. The following research questions have been addressed: (1) how consumer attitudes / perceived consumer behavior / subjective norms / environmental concern / past behavior affects Sri Lankan Millennials' purchase intention on green apparel products? (2) What is the moderating effect between consumer attitudes of purchase intention on green apparel products? This study investigated Sri Lankan millennials who use eco-friendly clothing. A research model is developed to examine the relationship between the dependent variable, customer purchase intention, and five important independent factors: attitudes, subjective norms, perceived control behavior, past behavior, and environmental concern. The moderating factor in this case is environmental concern between attitudes and purchase intention. This study's primary goal is to determine the connection between millennials' buying intentions and eco-friendly clothing products. The statistical research was based on 384 replies from millennials who use green clothing products. Standard statistical methods were used to test the scale's dependability. Regression analysis was used to test the hypothesis. Primary data was gathered via online and offline surveys, while secondary data was gathered from books and journals. Microsoft Excel and SPSS version 20 (Statistical Analysis Tool) were used to examine the collected data.

Keywords: Sustainability, Apparel Products, Millennials, Purchase Intention

1 INTRODUCTION

Due to the environmental pollution most of the countries embrace green concept. As a result of the green concept, the world is moving forward with green apparel. The past few decades have seen a crisis in the environment. Environmental protection is a significant problem. Sustainability issues like global warming and the depletion of natural resources have a direct or indirect impact on consumer decisions on goods purchases [1]. Western societies became aware of the need to protect the environment in the 1970s, having begun to do so in the early 1960s. Consequently, consumer green behavior in advanced Western countries has become the focus of a lot of research [2].

Consumers frequently accuse apparel companies of using unsustainable practices in their manufacturing and selling operations and the apparel sector is dealing with an increase in ethical and environmental challenges [3]. In order to reduce their carbon footprints, people are implementing eco-friendly practices such as using green products [2]. Apparel that combines environmentally friendly fashion and environmental responsibility at least a single element of environmental and social sustainability [4]. The apparel business has a detrimental effect on the environment, but it can also be seen in the reduction in textile reuse and re-

cycling as landfilling and incineration have been shown to be more environmentally friendly [5].

The procedure used in producing textiles and apparel needs a lot of energy and water, releases harmful dyes into the environment, and requires other finishing and ecosystem maintenance [6]. This research will investigate Factors Influencing Millennial Consumers' Purchase Intention towards Sustainable Apparel Products.

Today's world moves with sustainable fashion, but many millennial consumers in Sri Lanka are still close to fast fashion. This consumer buying pattern and buying behaviour is a challenge for brands to promote their sustainable apparel with the global trend. And other side the modern society is more concerned with the environment and is using green products because of the rise in environmental pollution and diseases like cancer / heart disease, asthma etc. They understand that if we maintain a healthy environment, we will be healthy as well.

This research study mainly examines the factors mainly impact to the millennial consumers' purchase intention towards sustainable apparel products. The main objective of this research is identifying the factors that mostly influence the sustainable apparel purchase intention. This research paper specifically focuses on examining the relationship between attitudes, perceived behavioral control, subjective norms, environmental concern, past behavior of green apparel purchase intention. This research mainly examines the moderating effect of environmental concern between consumer attitudes of green apparel purchase intention. The main purpose of this research is providing insights for Sri Lankan businesses how to enhance the sustainable products offering and positive behavioral changes of Sri Lankan millennial consumers.

2 MATERIALS AND METHODOLOGY

Going green plays a major part of human life all over the world. As a result of going green concept people move with green apparel products. The section describes the theoretical and practical cases of attitudes towards green apparel products, subject norms related to green purchase intention for sustainable apparel, perceived behavioral control, past behavior of green apparel products, environmental concern towards green apparel products environmental concern as moderator on attitudes, purchase intention of sustainable apparel products. This literature review discusses theory of planned behavior in relation to purchase intention. This researcher will investigate prior research findings, underlying hypotheses and conceptual framework.

2.1 *Purchase Intention*

What consumers think they will buy" is one definition for purchase intention [7]. One definition of green purchasing intention is the willingness of an individual to take into account and favor green production over traditional or conventional production when making decisions [8]. Customers who aim to invest in green clothing take into account how clothing affects the environment while purchasing sustainable and eco-friendly purchases [9]. The tendency of a person and willingness towards purchasing products with more environmentally friendly features over conventional ones is known as their "green purchase intention" [10]. A person's green buying intention is a reflection of their eco-friendly conduct in relation to their environmental issues [11]. Studies on green purchase intention are comparatively scarcer in Asian nations than in Western ones [10]. Measuring what people intend to do can sometimes underestimate their predictions future behavior rather than measuring what they expect to do [7].

2.2 *Theory of Planned Behavior*

The purpose of this research project is to examine the factors that influence the intention to purchase sustainable apparel goods in Sri Lanka, adopting the Theory of Planned Behavior. TPB is an expansion of TRA (Theory of Reasoned Action). The inclusion of cognitive behavioral control is the key difference between TPB and TRA (Ajzen, 1991). A model of prediction for persuasion that connects beliefs and actions is provided by Ajzen's TPB [12]. Ajzen and Fishbein kept concentrating on the elements that affect behavior and illustrated the connection between elements as intention, belief and attitude as well as subjective norms and perceived behavioral control [13]. The TPB essentially asserts that attitude behavior,

subjective norms, and perceived behavioral control or the ability or self-efficacy of carrying out that conduct will all influence to the development of an individual's behavioral intention and actual behavior [12]. According to the TBP -;

- Behavioral attitudes or beliefs, which can be defined as the level to which an individual views a behavior as favorable or negative [12].
- The term "subjective norm" or "normative beliefs" refers to a person's belief that important people approve or disapprove of his actions. Family members, friends, coworkers, or neighbors in close proximity might all be considered direct influences [12].
- Control beliefs, also known as "perceived behavioral control," are views of a challenge to acting in a way that suits one's interests or convenience in relation to opportunities, resources, and confidence in oneself [12].

Along with these factors, a number of other variables are also employed as predictors of purchase intention. Inserting is how it is discovered. These factors may contribute to TPB's enhanced predictive ability. The variables vary somewhat, including consumer values for a number of variables that are highly specific in particular contexts, like environmental knowledge and awareness / concern in connection to the intention to purchase sustainable goods and services or green purchase intention [14].

According to research [15] , Icek Ajzen and Martin Fisbein designed and produced TPB, an older theory of TRA. This hypothesis has been modified numerous times to better fit contemporary society. The TPB was created by extending the theory of reasoned action to include real and perceived behavioral control, allowing for the inclusion of additional predictor factors not previously included in the theory. Investigators frequently recommend other characteristics, such as affect expectation (the feelings I get from executing the action), self-identity (the degree to which I believe I am the type of person who engages in the conduct of interest), and past behavior (as a measure of habit strength)[15].

According to the [16] concept paper has investigated the purchase intention by using 3 independent variables as attitudes / subjective norms / perceived control behavior and environmental concern as the moderator.

2.3 *Attitudes*

According to psychological definitions, attitude is “a tendency expressed by evaluation of an exact entity with a certain amount of favor or disfavor” [7]. Extrinsic evaluations (OE) and behavioral beliefs (BB) combine to form attitude. The result of behavioral trust is personal trust. The corresponding positive or negative judgment of the potential repercussions of behavior is one of the outcomes of doing a behavior evaluation[17]. Multiple studies have provided empirical evidence for the positive correlation between green purchasing behavior and attitudes toward green products in the different geographical areas. In a study undertaken among customers in Indian urban areas, for instance, Khare (2015) identified a positive relationship between previous green opinions and environmentally conscious buying habits[2]. In the study of consumer purchase intention, attitude plays an essential part[7].

The attitude of customers toward eco-friendly clothing are a good determinant of the extent to which consumers purchase such clothing, as demonstrated by a variety of studies[4]. Sustainable purchases had a positive relationship with attitude. On the opposite hand, intention has little beneficial effect on sustainable purchasing behaviors[18].

2.4 *Subject Norms*

The concepts of "social norms" and "subjective norms" are frequently applied due to their considerable conceptual similarity[4]. The result of normative belief (NB) and compliance motivation (MC) is the subjective norm. Normative belief comply is a person's view of how others—those who are important to them—would prefer them to act in a certain circumstance, whereas motivation to comply is a person's wish to follow the advice of important people[17].External pressure from loved ones, friends, and important others the concept of planned behavior holds that decisions can be impacted by life [3]. Significantly positive assessment according to previous research, friends, family, peers, and relatives may significantly impact an individual's decision of purchasing a green purchase [2]. Research studies Customers are more likely to indicate a desire to buy environmentally friendly prod-

ucts when they have greater influence over their purchasing decisions [19].The researchers Nguyen et al. (2019), who investigated younger consumers, the element that influences the intention to buy most strongly is a subjective norm [3].

2.5 *Perceived Behavioral Control*

The term "PBC" describes the belief that certain actions are straightforward or rewarding. When someone is motivated, they will act in a certain way and can act without any justification [1]. Customer comprehension improves by exercising behavioral control over the challenges they face, consumers are more inclined to purchase sustainable goods [14]. Control beliefs (CB) and perceived power (PP) combine to produce perceived behavioral control. Although perceived power refers to an individual's assessment of the influence of these factors in facilitating or impeding a specific behavior, control belief is the belief of an individual regarding the existence of certain factors (such as time, money, and opportunity) that may facilitate or impede the performance of a particular behavior[17]. Based on previous studies, one of the best indicators of people's intentions and actions toward a variety of green products is perceived behavioral control [2]. An essential component of planning theory is cognitive behavioral control "Behavioral Achievements" can be used to predict behavior directly, in addition to behavioral intention [20]. In order to handle circumstances in which an individual is unable to fully exhibit voluntary control over their actions, the PBC configuration was included [21].

2.6 *Past Behavior*

The idea of incorporating prior conduct TPB enhances the ability to search for present buying intentions [9]. The strongest evidence pertains to the role of prior conduct, despite the fact that a number of TPB enhancements have been suggested. According to Sutton (1994), behavior may be influenced more by prior behavior than by the considerations outlined in the TPB model when performance is repeated[22]. When the relevant activity is repeated, special attention should be paid to previous behavior .Because consumer behaviors, like the decisions to buy food, are frequently repeated, it is important to evaluate the impact of the TPB's constructs while adjusting for the effects of prior behavior[23]. The capacity to overcome these kinds of barriers and the existence of enabling elements like prior experience determine how much control people actually have over their conduct [15].According to the [9] and [24] past behavior doesn’t has a positive impact to the green apparel purchase intention.

2.7 *The Role of Environmental Concern*

Environmental concern refers to an individual's level of worry over environmental issues. It demonstrates their attempts at solving difficulties as well as their role in offering answers [14]. Their environmental impact is greatly influenced by environmental issues and consumer awareness. Customers are becoming more knowledgeable, which is indicative of an increasing trend toward environmentally sustainable purchases[25]. Individuals' EC can be achieved through a variety of strategies,from particular attitudes to real actions (like recycling). Environmentally friendly product consumption); nevertheless, the effect on consumers' environmental concern is already present, and research on consumer behavior has produced conflicting findings [25]. According to [26] & [27], environmental concern towards sustainable products has a positive impact of purchase intention. According to the [28] environmental concern doesn’t moderate the relationship between attitudes towards sustainable apparel and purchase intention of Indonesian consumers. Also examined were the moderating effects of perceived consumer efficacy and environmental concern. The findings showed that perceived value, green purchase intention, and environmental knowledge were all strongly influenced by both variables [19]. [16] explored about the relationship between moderating factors of environmental concern between attitudes, subjective norms and perceived behavioral control by publishing concept paper.

3 METHODOLOGY

The methodology chapter of this research will be covered the conceptual framework. This is deductive research discuss here

about the millennial consumers' purchase intention towards sustainable apparel products. A deductive approach to data used to test the hypotheses generally associated with quantitative research. Second, this thesis uses a survey and the quantitative approach for collecting obtaining data to support its objective quickly reaches people in the public[20].This research examines relationship between green purchase intention on sustainable apparel products.

This study used a positivist approach, which is grounded in measurable facts and actual data. This study is grounded in empirical evidence and measurable facts. Structured approach with the goal of identifying trends that can be applied to a larger group.

Target population of this research study is millennial consumers who purchase green apparel products in Sri Lanka.

This research study mainly focuses on purchasing intention of sustainable apparel products. Therefore, nowadays sustainable apparel products are in high demand and consumers mostly spend for apparel products which are good for the environment and themselves. In here we mainly consider sustainable apparel products which are made from eco-friendly materials (organic / recycled fiber / cotton / bamboo).

According to the research topic population of Millennial customers of Sri Lanka is 4 742 000 in 2024 [29]. Sample size have been calculated using the table Krejcie and Morgan table. Based on Morgan table with 5% error level and 95% confidence level, this research study will be used 384 as sample size.

The Statistics Package for Social Sciences (SPSS) version 20 was used for analyzing the data. Research methods such as regression analysis, correlation and descriptive statistics.

4 FINDINGS

4.1 *Reliability Testing*

Table 1. Cronbach's alpha reliability testing

Variable Name	Cronbach 's Alpha	Reliability	Conclusion
ATT	0.882	0.882 > 0.7	Reliable
PBC	0.805	0.805 > 0.7	Reliable
SN	0.902	0.902 > 0.7	Reliable
PB	0.856	0.856 > 0.7	Reliable
EC	0.842	0.842 > 0.7	Reliable
PI	0.811	0.811 > 0.7	Reliable

All of the factors in this study have alpha values greater than 0.700. Table 09 displays subjective norms with the highest value on the intention to purchase green clothing. With Cronbach's alpha of 0.902, perceived behavioral control towards sustainable products represented the lowest values in the chart.

4.2 *Correlation Analysis*

Table 2. Correlation between purchase intention and attitudes towards green sustainable products

Correlations			
		ATT	PI
ATT	Pearson Correlation	1	.374**
	Sig. (2-tailed)		<.001
	N	384	384
PI	Pearson Correlation	.374**	1
	Sig. (2-tailed)	<.001	
	N	384	384

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

Table 2 shows that purchase intention for sustainable products and attitudes towards sustainable products have a moderate, positive and statistically significant relationship. Furthermore, the correlation is 37.4%. The significant value is less than 0.01. There's a significant relationship between purchase intention for sustainable products and attitudes towards sustainable products.

Table 3. Correlation between purchase intention and PBC towards green sustainable products

Correlations		
	PBC	PI
Pearson Correlation	1	.190**
Sig. (2-tailed)		<.001
N	384	384
Pearson Correlation	.190**	1
Sig. (2-tailed)	<.001	
N	384	384

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

Table 3 shows that purchase intention for sustainable products and perceived behavioral control towards sustainable products have a weak but positive relationship. Furthermore, the correlation is 19%. The significant value is less than 0.01. There's a weak but statistically significant positive relationship between purchase intention for sustainable products and perceived behavioral control towards sustainable products.

Table 4. Correlation between purchase intention and PB towards green sustainable products

Correlations			
		PB	PI
PB	Pearson Correlation	1	.183**
	Sig. (2-tailed)		<.001
	N	384	384
PI	Pearson Correlation	.183**	1
	Sig. (2-tailed)	<.001	
	N	384	384

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

Table 4 shows that purchase intention for sustainable products and past behavior towards sustainable products have a weak but positive relationship. Furthermore, the correlation is 18.3%. The significant value is less than 0.01. There's a weak but statistically significant positive relationship between purchase intention for sustainable products and past behavior towards sustainable products.

Table 5. Correlation between purchase intention and EC towards green sustainable products

Correlations			
		EC	PI
EC	Pearson Correlation	1	.542**
	Sig. (2-tailed)		<.001
	N	384	384
PI	Pearson Correlation	.542**	1
	Sig. (2-tailed)	<.001	
	N	384	384

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

Table 5 shows that purchase intention for sustainable products and environment concern towards sustainable products have a moderate, positive and linear relationship. Furthermore, the correlation is 54.2%. As the significant value is less than 0.01. There's a significant relationship between purchase intention for sustainable products and attitudes towards sustainable products.

4.3 *Multiple Regression Analysis*

Table 6. Multiple regression model summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.601[a]	.361	.352	.42352

a. Predictors: (Constant), EC, PB, PBC, ATT, SN

The effects of attitudes perceived behavioral control, subjective norms, perceived benefits, and environmental concern on purchase intention were investigated using a multiple regression analysis.

The model had a modest level of explanatory power, accounting for 36.1% of the variance in purchase intention (R square = 0.361, Adjusted R square = 0.352).
R = 0.601 represented the overall correlation between the independent factors and purchasing intention.

Table 7. Multiple regression ANOVA table

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	38.271	5	7.654	42.672	<.001[b]
	Residual	67.802	378	.179		
	Total	106.073	383			

a. Dependent Variable: PI
b. Predictors: (Constant), EC, PB, PBC, ATT, SN

Purchase intention is substantially predicted by the independent variables (attitudes, perceived behavioral control, subjective norms, perceived benefits, and environmental concern), according to the statistically significant regression model (F(5, 378) = 42.672, P <0.001). The model's good match to the data is confirmed by this.

Table 8. Multiple regression coefficients

Coefficients						
		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	1.197	.210		5.691	<.001
	ATT	.123	.037	.153	3.348	<.001
	SN	.095	.032	.147	2.986	.003
	PBC	.000	.042	.000	.003	.997
	PB	.035	.022	.076	1.596	.111
	EC	.441	.045	.452	9.869	<.001
a. Dependent Variable: PI						

Regression research shows how different factors affect millennials in Sri Lanka's desire to buy green clothing products (PI). The baseline level of purchase intention, when all independent variables are zero, is represented by the constant value (B = 1.197, p <.001). Attitude (ATT) is one of the predictors that has a positive and statistically significant effect on purchase intention (B = 0.123, p <.001), suggesting that good consumer attitudes increase the intention to buy sustainable apparel.

Subjective Norms (SN) also exhibit a strong positive correlation (B = 0.095, p =.003), indicating a major role for peer pressure and social factors. Customers who are more concerned about the environment are more likely to plan to buy green clothing, as seen by the largest effect of Environmental Concern (EC) (B = 0.441, p <.001).

Perceived behavioral control (PBC) (B = 0.000, p =.997) and past behavior (PB) (B = 0.035, p =.111) were found to be statistically insignificant, indicating that they do not significantly affect purchase intention in this model. Millennials in Sri Lanka are mostly motivated to purchase sustainable clothing by attitude, subjective norms, and environmental concerns.

4.4 *Moderation Regression Analysis*

Table 9. Moderation regression model summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.589[a]	.347	.342	.42695
a. Predictors: (Constant), Interaction, Zscore(EC), Zscore(ATT)				

34.7% of the variance in purchase intention can be explained by the multiple regression model that incorporates attitude, environmental concern, and their interaction (R Square = 0.347), according to the model summary. There is a strong model fit because R square vale is greater than 0.5.

Even after accounting for the number of predictors and determining the sample size, the model continues to explain a sizable amount of the variance, as seen by the adjusted R square = 0.342. An average standard error the observed values and the regression line is indicated by the standard error of the estimate (0.42695).

5 CONCLUSION

The main conclusions of the study are outlined in this chapter and are connected to the research questions and hypotheses.Millennials in Sri Lanka are highly influenced by attitudes, subjective standards, and perceived behavioral control when it comes to their intention to purchase sustainable clothing.
The association between attitude and purchase intention is strongly moderated by environmental worry, but there is no direct correlation between past activity and environmental concern.The results provide significant new information to the body of literature by confirming some theories and disproving others. In order to increase the uptake of green clothing among young Sri Lankan customers, the study emphasizes the significance of focusing marketing strategies on attitudes and eco-conscious values.

Q1. How consumer attitudes / perceived consumer behavior / subjective norms / environmental concern / past behavior affects Sri Lankan Millennials' purchase intention on green apparel products?

According to the previous kinds of literature, attitudes / perceived consumer behavior / subjective norms / environmental concern and past behavior have significant relationship with purchase intention of sustainable garments. According to the correlation analysis Sri Lankan millennials' atti-

tudes and purchase intention for sustainable have a 0.374 Pearson correlation and that means both of variables have a moderate, positive and statistically significant relationship. According to the correlation analysis Sri Lankan millennials' PBC and purchase intention for sustainable have a 0.190 Pearson correlation and that means both of variables have a weak but positive relationship. According to the correlation analysis Sri Lankan millennials' subjective norms and purchase intention for sustainable have a 0.303 Pearson correlation and that means both of variables have a moderate, positive and statistically significant relationship. According to the correlation analysis Sri Lankan millennials' past behavior and purchase intention for sustainable have a 0.183 Pearson correlation and that means both of variables have a moderate, positive and statistically significant relationship. According to the correlation analysis Sri Lankan millennials' environment concern and purchase intention for sustainable have a 0.542 Pearson correlation and that means both of variables have a moderate, positive and statistically significant relationship.

According to the multiple regression analysis also attitudes of Sri Lankan millennials', subjective norms of Sri Lankan millennials' and perceived behavioral control of Sri Lankan millennials' have significant effects with purchase intention of sustainable clothing. According to that, Hypothesis H1- Sri Lankan Millennials' Attitudes toward sustainable apparel products has a significant impact on purchase intention / H2 - Sri Lankan Millennials' perceived behavioral control toward sustainable apparel products has a significant impact on purchase intention and H3 - Sri Lankan Millennials' subjective norms toward sustainable apparel products has a significant impact on purchase intention. Based on multiple regression analysis past behavior of Sri Lankan millennials', environment concern of Sri Lankan millennials' do not have significant effects with purchase intention of sustainable clothing. According to that, Hypothesis H4 - Past Behavior towards sustainable apparel products has a significant impact on purchase intention & H5 – Environment Concern towards sustainable apparel products has a significant impact on purchase intention are rejected.

According to the multiple regression analysis, millennials'' attitudes / subjective norms and environment concern significantly increase the purchase intention of sustainable clothes. PBC and PB do not have a strong or significant in this model.

Q2. What is the moderating effect between consumer attitudes of purchase intention on green apparel products?

According to the previous kinds of literature, Environmental Concern significantly moderates the relationship between attitude and purchase intention towards sustainable apparel. Based on moderation regression analysis, from interaction term in the regression model showed the moderating relationship between millennials' attitudes and purchase intention on green apparel products. The interaction term (Attitudes * EC) has a positive coefficient value (B = 0.06) and it's statistically significant because the sig value of that is <.001.

According to the results of the moderation regression analysis , environmental concern strengths the relationship between millennials' attitudes and purchase intention of sustainable garments.

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Determinants of User Acceptance in Public Transit Digitization: An Extended UTAUT Analysis of the SLTB eSeat.LK Platform

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ABSTRACT: This study examines the factors influencing passenger adoption of the Sri Lanka Transport Board's (SLTB) web-based reservation platform, eSeat.LK. By extending the Unified Theory of Acceptance and Use of Technology (UTAUT) framework to include perceived risk, the research investigates the primary drivers and barriers to digital transit service acceptance. A quantitative, cross-sectional research design utilized stratified sampling to survey 380 long-distance bus passengers possessing prior online ticketing experience. Multiple regression analysis confirmed the measurement instrument's robust validity and explained 54.2% of the variance in behavioral intention. Results demonstrated that performance expectancy, effort expectancy, social influence, and facilitating conditions significantly and positively influenced adoption intent. Furthermore, lower perceived risk (higher perceived safety) positively correlated with platform adoption. These empirical findings provide actionable insights for transit authorities, emphasizing the critical need to enhance transaction security and deploy dedicated mobile solutions within Sri Lanka's telecommunications landscape.

Keywords: Public Transit Digitization, UTAUT, Perceived Risk, Technology Adoption, Sri Lanka

1 INTRODUCTION

1.1 *Background of the Study*

Public transportation plays a vital role in socio-economic development by providing essential mobility to daily commuters, students, professionals, and entrepreneurs. In developing economies such as Sri Lanka, inter-provincial travel relies heavily on long-distance bus transport networks. The Sri Lanka Transport Board (SLTB), as the state-owned enterprise overseeing public bus transit, historically managed seat reservations through traditional, counter-based ticketing systems. This conventional approach was characterized by physical queuing at central bus terminals, administrative inefficiencies, manual record-keeping, susceptibility to overbooking, and substantial time costs for commuters.

In response to global shifts toward e-government service delivery, and supported by Sri Lanka's high smartphone penetration and expanding telecommunications infrastructure, the SLTB introduced the eSeat.LK online seat reservation platform. The system was designed to modernize public transit management by offering real-time seat availability schedules, remote booking access, and integrated online payment gateways. However, rather than representing a fully realized digital transformation, eSeat.LK serves as a transitional web-based baseline for public transport digitization. In practice, the platform operates within a broader technological landscape marked by intermittent infrastructure challenges, including occasional server downtime, technical glitches, and varying levels of user digital readiness. A comprehensive evaluation of passenger adoption within this opera-

tional context is essential to guide the transition from web-based baselines toward robust mobile-first transportation solutions.

1.2 *Problem Statement*

Although the eSeat.LK platform provides a modern alternative to counter-based ticketing, transitioning public transit commuters from traditional offline channels to electronic booking systems introduces distinct user challenges. The adoption of Information and Communication Technology (ICT) for public sector services historically lags behind private sector e-commerce platforms due to disparities in user digital literacy, institutional trust, and system dependability. While eSeat.LK remains functional, empirical literature investigating the specific determinants governing passenger usage or non-usage of state-managed transit platforms in Sri Lanka remains sparse.

Existing research often neglects the interplay between facilitating technological factors and operational barriers—such as system reliability issues, transaction uncertainty, and platform downtime—that uniquely characterize public sector platforms. Without a scientific evaluation grounded in established technology acceptance models, transit authorities lack the empirical evidence needed to determine whether adoption barriers stem from usability constraints, lack of technological support, or security concerns. This knowledge gap hinders the SLTB from resolving technical bottlenecks, optimizing platform usability, and designing targeted user-acquisition strategies required to support future native mobile application development.

1.3 *Research Objectives*

To address the empirical gap, this study extends the Unified Theory of Acceptance and Use of Technology (UTAUT) framework to analyze both facilitating determinants and inhibiting factors influencing public transit reservation adoption. The primary objectives of this study are:

1. To examine the influence of Performance Expectancy on passenger behavioral intention to adopt the eSeat.LK platform.
2. To examine the influence of Effort Expectancy on passenger behavioral intention to adopt the eSeat.LK platform.
3. To examine the influence of Social Influence on passenger behavioral intention to adopt the eSeat.LK platform.
4. To examine the influence of Facilitating Conditions on passenger behavioral intention to adopt the eSeat.LK platform.
5. To examine the influence of Perceived Risk as an inhibiting factor on passenger behavioral intention to adopt the eSeat.LK platform.

2 LITERATURE REVIEW

2.1 *Theoretical Framework: The UTAUT Model*

This study is grounded in the Unified Theory of Acceptance and Use of Technology (UTAUT) introduced by Venkatesh et al. [1]. The UTAUT model synthesizes eight prominent theories of technology acceptance, including the Technology Acceptance Model (TAM), Theory of Planned Behavior (TPB), and Innovation Diffusion Theory (IDT). The model posits four core constructs—Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions—as direct determinants of behavioral intention and ultimate system usage. The UTAUT framework has been extensively validated across various digital service contexts, including e-banking, e-government, health informatics, and online ticketing, providing a highly robust and empirically tested foundation for evaluating public transit digitalization.

2.2 *Constructs and Hypotheses Development*

Performance Expectancy (PE): Performance Expectancy reflects the degree to which an individual believes that using a system will enhance their task performance. In the context of eSeat.LK, PE denotes the platform's perceived utility in facilitating efficient trip planning, securing reservations, and eliminating physical queuing times. Prior ICT adoption studies consistently identify PE as the strongest predictor of behavioral intention [2]. Therefore, it is hypothesized that:

– H1: Performance Expectancy has a significant positive influence on passengers' behavioral intention to adopt the eSeat.LK platform.

Effort Expectancy (EE): Effort Expectancy represents the degree of ease associated with

the use of the system. For eSeat.LK, this encompasses user perceptions regarding the platform's navigability, interface intuitiveness, and the simplicity of the online payment process. Systems characterized by steep learning curves or complex interfaces inherently deter adoption. Previous empirical research on digital payments in Sri Lanka underscores EE as a critical determinant of user acceptance [3]. Thus, it is hypothesized that:

- H2: Effort Expectancy has a significant positive influence on passengers' behavioral intention to adopt the eSeat.LK platform.

Social Influence (SI): Social Influence is defined as the degree to which an individual perceives that important others—such as family, friends, and peers—believe they should use the new system. Within Sri Lanka's highly collectivist cultural context, social validation and word-of-mouth recommendations strongly shape consumer behavior. Research investigating digital banking and social commerce [4], [5] corroborates that social endorsement significantly elevates the probability of technological adoption. Consequently, it is hypothesized that:

- H3: Social Influence has a significant positive influence on passengers' behavioral intention to adopt the eSeat.LK platform.

Facilitating Conditions (FC): Facilitating Conditions refer to the extent to which a user believes that the necessary organizational and technical infrastructure exists to support system use. This includes access to required resources, such as smartphones, reliable internet connectivity, and adequate user support. Given the varying levels of digital infrastructure across Sri Lanka, FC is a critical variable. Prior studies on e-government and digital services in Sri Lanka [6], [7] identify device access and reliable connectivity as indispensable enablers for continuous system utilization. Therefore, it is hypothesized that:

- H4: Facilitating Conditions have a significant positive influence on passengers' behavioral intention to adopt the eSeat.LK platform.

Perceived Risk (PR): Perceived Risk is integrated as an extension to the standard UTAUT model to account for the uncertainties and vulnerabilities inherent in online public sector transactions. PR encompasses the potential for loss in the pursuit of a desired outcome when using an e-service. In the context of online transit ticketing, PR primarily manifests as financial risk (fears of transaction fraud or payment gateway failure), privacy risk (unauthorized data disclosure), and performance risk (the system failing to accurately secure the booked seat). Extant literature confirms that apprehensions regarding data privacy and transaction reliability severely inhibit digital adoption [8], [9]. To maintain theoretical consistency, this study models risk as a fundamental barrier to acceptance. Thus, it is hypothesized that:

- H5: Perceived risk negatively influences passengers' behavioral intention to adopt the eSeat.LK platform.

3 METHODOLOGY

3.1 *Research Design and Sampling Strategy*

This study adopts a quantitative, explanatory, cross-sectional research design to empirically test the hypothesized relationships derived from the extended Unified Theory of Acceptance and Use of Technology (UTAUT) framework [10]. The target population comprises adult passengers using long-distance, inter-provincial bus transit services managed by the Sri Lanka Transport Board (SLTB) on routes where eSeat.LK online reservations are available.

To ensure adequate geographical and demographic representation across major transit corridors, a stratified sampling strategy was employed. A total of 390 questionnaires were administered across physical and digital channels. Following rigorous data screening to eliminate incomplete or unengaged responses, a final valid sample of 380 respondents (N = 380) was retained for hypothesis testing, providing statistical power for multiple linear regression analysis.

To confirm that respondents possessed sufficient technological baseline awareness to evaluate digital ticketing, screening items assessed prior online reservation experience. All 380 participants (100%) confirmed prior experience with online ticketing platforms, categorized into train reservations only (37.37%), bus reservations only (31.32%), and experience with both modes (31.32%).

3.2 *Conceptual Framework*

The conceptual model expands the original UTAUT architecture by integrating Perceived Risk (PR) alongside the standard antecedents of adoption: Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), and Facilitating Conditions (FC). The dependent variable is Behavioral Intention (BI) to adopt the eSeat.LK platform.

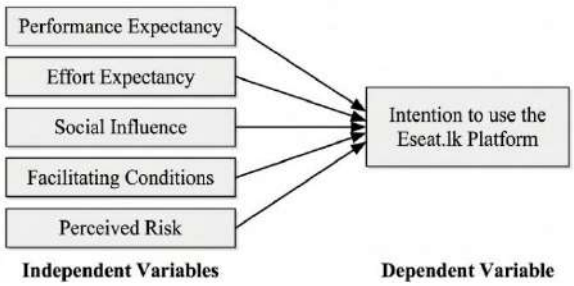


Figure 1. Conceptual framework of the study based on the Extended UTAUT model

3.3 *Data Collection Instrument and Operationalization*

Data were gathered using a structured, self-administered questionnaire administered via a dual-mode approach: physically at major inter-provincial bus terminals across Sri Lanka, and digitally via web-based survey distribution targeting long-distance commuter groups. The instrument was structured into two sections:

- Part A: Captured demographic attributes (age, gender, education level, travel frequency) and prior digital ticketing experience.
- Part B: Measured the core theoretical constructs using a 5-point Likert scale ranging from 1 (“Strongly Disagree”) to 5 (“Strongly Agree”).

Construct items were adapted from established UTAUT literature [1], [10]. Perceived Risk items (Q.25–Q.31) measured financial, performance, and privacy risk concerns. These items were reverse coded during dataset preparation so that higher composite scores represent greater perceived safety (lower perceived risk), establishing mathematical consistency for regression modeling.

3.4 *Construct Validity, Reliability, and Diagnostic Testing*

To address reviewer requirements regarding measurement rigor and statistical assumptions, construct validity, scale reliability, and regression diagnostics were systematically evaluated prior to hypothesis testing.

- Construct Validity and Reliability: Internal consistency and convergent validity were established across all constructs. Average Variance Extracted (AVE) values ranged from 0.671 to 0.738, comfortably exceeding the recommended 0.50 threshold. Composite Reliability (CR) values ranged from 0.894 to 0.934, surpassing the standard 0.70 threshold.
- Normality Assessment: Data distribution was verified using univariate Skewness and Kurtosis statistics. Skewness values ranged between –0.316 and –0.078, while Kurtosis values ranged between –0.850 and –0.250, confirming normal distribution suitable for parametric testing.
- Multicollinearity Diagnostics: Potential collinearity among predictor variables was assessed using the Variance Inflation Factor (VIF). All VIF values remained below 3.0, well below the conservative threshold of 5.0, confirming the absence of severe multicollinearity.

3.5 *Ethical Considerations*

Prior to data collection, informed consent was obtained from all 380 survey respondents. Participants were provided with a brief clear statement detailing the study’s purpose, assured that participation was entirely voluntary, and guaranteed full anonymity and data confidentiality. No personal identifiable information was collected or stored.

4 DATA PRESENTATION AND ANALYSIS

4.1 *Demographic Analysis*

Data screening and cleaning of the initial responses resulted in a final valid sample of 380 respondents (N = 380), strictly aligning with the methodology parameters. Demographic profiling indicated a slight male majority (54%) compared to female respondents (46%). The majority of the sample (68%) fell within the 18–35 age demographic, suggesting that younger, digitally literate cohorts constitute the primary user base for electronic transit ticketing. Regarding travel frequency, 42% of the respondents indicated they travel on SLTB long-distance routes at least once a month.

4.2 *Reliability and Validity*

To address the requisite measurement standards for the extended UTAUT model, construct reliability and convergent validity were assessed prior to hypothesis testing. As shown in Table 1, Cronbach's Alpha coefficients for all constructs exceeded the 0.70 threshold. Furthermore, Composite Reliability (CR) and Average Variance Extracted (AVE) were evaluated. All CR values surpassed the 0.70 benchmark (ranging from 0.894 to 0.934), and all AVE values exceeded the 0.50 threshold (ranging from 0.671 to 0.738), confirming robust internal consistency and convergent validity across the survey instrument.

Table 1. Reliability and validity metrics

Variable	Number of Items	Cronbach's Alpha	Composite Reliability (CR)	Average Variance Extracted (AVE)
Behavioral Intention (BI)	3	0.865	0.912	0.725
Performance Expectancy (PE)	4	0.892	0.925	0.738
Effort Expectancy (EE)	4	0.814	0.894	0.671
Social Influence (SI)	5	0.843	0.908	0.685
Facilitating Conditions (FC)	7	0.888	0.915	0.710
Perceived Risk (PR)*	3	0.901	0.934	0.730

*Note: PR items were reverse-coded prior to reliability analysis.

4.3 *Regression Diagnostics*

Before executing the multiple regression analysis, fundamental statistical assumptions were verified. Data normality was confirmed, with Skewness values ranging between –0.316 and –0.078, and Kurtosis values ranging between –0.850 and –0.250, well within acceptable bounds for parametric testing. Additionally, the Variance Inflation Factor (VIF) values for all independent variables were assessed to test for multicollinearity. As detailed in Table 4, all VIF values remained below 1.5, confirming the absence of multicollinearity issues.

4.4 *Multiple Regression Analysis*

Multiple linear regression was conducted to determine the collective and individual effects of the independent variables (PE, EE, SI, FC, and PR) on the dependent variable (Behavioral Intention).

Table 2. Regression model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.736	.542	.536	.40249	1.872

Table 3. Analysis of variance (ANOVA)

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	74.453	5	14.891	91.918	<.001
Residual	62.208	374	.162		
Total	136.661	379			

Table 2 demonstrates an R Square value of 0.542, indicating that 54.2% of the total variance in passengers' Behavioral Intention to use eSeat.LK is explained by the five independent constructs. The ANOVA results in Table 3 report a highly significant F-statistic ($F = 91.918$, $p < .001$), validating the overall fitness of the extended UTAUT model in predicting adoption intent.

Table 4. Coefficients and collinearity statistics

Variable	Unstandardized B	Std. Error	Standardized Beta (β)	t-value	Sig. (p)	Tolerance	VIF
(Constant)	-.613	.223		-2.746	.006		
Performance Expectancy (PE)	.287	.039	.281	7.398	<.001	.845	1.183
Effort Expectancy (EE)	.269	.041	.260	6.570	<.001	.780	1.282
Social Influence (SI)	.236	.043	.227	5.510	<.001	.721	1.387
Facilitating Conditions (FC)	.181	.039	.183	4.601	<.001	.777	1.288
Perceived Risk (PR)*	.155	.042	.145	3.732	<.001	.806	1.241

Table 4 illustrates the individual contribution of each predictor. Based on the Standardized Beta coefficients, Performance Expectancy ($\beta = .281$, $p < .001$) exerts the strongest positive influence on Behavioral Intention, followed by Effort Expectancy ($\beta = .260$, $p < .001$), Social Influence ($\beta = .227$, $p < .001$), and Facilitating Conditions ($\beta = .183$, $p < .001$). Consequently, Hypotheses H1, H2, H3, and H4 are strongly supported.

Addressing Hypothesis 5 (Perceived Risk): Hypothesis 5 posited that perceived risk negatively influences passengers' intention to adopt the platform. Table 4 reports a positive Standardized Beta coefficient for this construct ($\beta = .145$, $p < .001$). As established in the methodology, the survey items measuring Perceived Risk were reverse-coded during data preparation. Consequently, higher numerical scores on this specific construct reflect lower perceived risk (i.e., higher perceived safety). The positive beta coefficient, therefore, mathematically confirms that as a passenger's perceived safety increases (and perceived risk decreases), their behavioral intention to adopt eSeat.LK increases. This corrects the logical contradiction often found in risk-adoption modeling and empirically supports H5.

5 DISCUSSION

The primary objective of this study was to evaluate the multifaceted determinants of passenger adoption for the SLTB eSeat.LK web reservation platform. By empirically validating an extended UTAUT framework, the findings confirm that cognitive, social, environmental, and risk-related factors collectively shape user behavioral intentions within Sri Lanka's evolving public transit sector.

Performance Expectancy emerged as the strongest predictor of adoption intent ($\beta = .281$). This underscores the pragmatic nature of Sri Lankan commuters; the tangible utility of bypassing physical terminal queues, saving time, and securing guaranteed seating serves as the primary catalyst for transitioning to digital ticketing. Effort Expectancy also demonstrated a highly significant influence ($\beta = .260$). For a state-managed public service to achieve mass adoption, the platform must remain highly intuitive and navigable. Because eSeat.LK currently operates as a web-based platform rather than a dedicated mobile application, minimizing the learning curve is critical to accommodate non-digital natives and reduce the friction associated with web browser navigation on mobile devices.

The significant impact of Social Influence ($\beta = .227$) strongly aligns with Sri Lanka's collectivist cultural dynamics. In environments where institutional trust in digital services is still developing, word-of-mouth endorsements, peer recommendations, and positive user reviews serve as essential trust-building mechanisms. Furthermore, Facilitating Conditions ($\beta = .183$)—specifically smartphone ownership, reliable mobile broadband connectivity, and accessible technical support from the SLTB—are indispensable enablers. Acknowledging the intermittent infrastructure challenges and varying levels of digital readiness across the country, these underlying technological realities dictate the practical feasibility of sustained platform usage.

Finally, the analysis empirically validates the critical role of Perceived Risk in transit platform adoption. Addressing previous theoretical contradictions, the positive beta coefficient ($\beta = .145$) for this reverse-coded construct confirms that higher perceived safety (and consequently, lower perceived risk) is significantly and positively associated with passenger adoption intent. This finding highlights a persistent barrier in developing digital economies: passengers harbor acute apprehensions regarding online payment gateway security, data privacy, and operational system malfunctions. A primary performance risk identified is the fear of transaction failure—such as successfully purchasing a ticket online only to have the physical bus conductor fail to recognize or validate the digital receipt. Therefore, mitigating these risks through robust system reliability, transparent payment processing, and standardized conductor verification protocols is paramount to driving user trust and long-term platform adoption.

6 CONCLUSION AND RECOMMENDATIONS

6.1 *Conclusion*

Digitizing public transportation through platforms such as eSeat.LK represents an es-

sential step for the Sri Lanka Transport Board (SLTB) in modernizing state-managed transit services. This study successfully utilized an extended Unified Theory of Acceptance and Use of Technology (UTAUT) framework to evaluate passenger adoption determinants within Sri Lanka's public bus transit sector. The multiple linear regression model accounted for 54.2% (R^2 = 0.542) of the variance in behavioral intention to adopt eSeat.LK. All five hypothesized constructs—Performance Expectancy, Effort Expectancy, Social Influence, Facilitating Conditions, and Perceived Risk—exerted statistically significant influences on adoption intent, validating the extended theoretical model within a developing economy context.

6.2 *Theoretical Contributions*

This research contributes to the technology acceptance literature by extending the UTAUT framework into the public transportation domain of a South Asian developing nation. By incorporating Perceived Risk alongside standard performance and effort antecedents, the study provides empirical evidence on how security, financial, and operational apprehensions act as key barriers in state-managed digital services. Furthermore, the explicit operationalization and reverse-coding of the risk construct resolve common theoretical ambiguities regarding beta coefficient directions, offering a clearer methodological framework for future risk-adoption research in public sector digitization.

6.3 *Practical and Managerial Implications*

The empirical findings offer actionable insights for transit authorities, policymakers, and platform developers:

- Deployment of a Native Mobile Application: Because eSeat.LK currently operates as a web-based baseline, a primary recommendation for the SLTB is the future development and deployment of a dedicated, native mobile application. A mobile app would capitalize on Sri Lanka's high smartphone penetration, streamline navigation, and eliminate browser-based friction for daily commuters.
- Risk Mitigation and Operational Reliability: To alleviate user apprehensions regarding financial loss and service failure, the SLTB must integrate globally recognized, secure payment gateways, publish clear refund policies, and issue standardized digital verification devices for bus conductors to ensure seamless ticket validation. Establishing a dedicated, responsive customer support hotline for e-ticketing queries will further build user trust.
- Usability Enhancements: Given the strong impact of Effort Expectancy, platform developers must prioritize intuitive user interface (UI) design, ensuring simple booking workflows that cater to non-digital natives.
- Leveraging Social Proof: To capitalize on Social Influence, the SLTB should execute targeted promotional campaigns and incorporate user review mechanisms, utilizing word-of-mouth dynamics inherent in Sri Lanka's collectivist culture to drive platform adoption.

6.4 *Limitations and Future Research Directions*

Several methodological limitations should be acknowledged to contextualize the findings:

- Study Design: The research utilized a cross-sectional design, capturing passenger perceptions at a single point in time. Consequently, while the regression model identifies strong predictive relationships, it cannot establish definitive temporal causality or observe how initial adoption intentions evolve into long-term usage habits over time.
- Sampling and Generalizability: Although stratified sampling ensured broad coverage across major transit corridors, the sample was limited to passengers with baseline digital awareness (100% prior online ticketing experience). This restricts the direct generalizability of the findings to non-digitally active or rural commuter populations.

Future research should employ longitudinal designs to track continuous platform usage over time. Additionally, scholars are encouraged to investigate the moderating effects of demographic variables—such as age, income, and digital literacy—and expand the framework to evaluate multi-modal

reservation systems across combined bus and rail networks.

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Organizational Information Maturity as a Foundation for HR Digitalization Success: Developing the HR Digitalization Success Matrix (HDSM)

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ABSTRACT: Organizations continue to invest heavily in Human Resource Information Systems, Human Resource Analytics, artificial intelligence, and digital workforce technologies; however, the outcomes of HR digital transformation significantly vary across organizations. Existing scientific publications and practices have largely focused on technology adoption, analytics capability, and digital maturity, providing limited explanation for why organizations with similar technological investments achieve different transformation outcomes. This study develops the HR Digitalization Success Matrix (HDSM), a conceptual framework that integrates Organizational Information Maturity and HR Digitalization Success into a single classification model. The framework was developed through a structured review of approximately fifty academic publications, practitioner interviews, and longitudinal experience mapping derived from more than fifteen years of HR digital transformation practice. The proposed matrix classifies organizations according to their information maturity and digitalization success, identifying distinct organizational maturity states and progression pathways. The study argues that sustainable HR digital transformation depends not only on technology adoption but also on information quality, data governance, leadership engagement, analytics capability, and information culture. HDSM offers a theoretical foundation for future research and a practical diagnostic tool for organizations pursuing digital transformation.

Keywords: HR digitalization, digital transformation, organizational information maturity, HR analytics, digital maturity, information governance, HRIS, conceptual framework

1 INTRODUCTION

Digital transformation has become a strategic priority for organizations seeking to improve efficiency, decision-making quality, and competitive advantage. Within this broader transformation agenda, Human Resource Management has experienced significant digitalization through the adoption of Human Resource Information Systems, Human Resource Analytics, artificial intelligence applications, and digital workforce platforms. Organizations increasingly invest in these technologies with the expectation that digital HR functions will improve workforce management, support evidence-based decision-making, and contribute to organizational performance. Despite substantial investments in digital technologies, many organizations continue to experience varying levels of success in achieving meaningful HR digital transformation outcomes.

Existing research has identified numerous factors influencing digital transformation success, including technology capability, analytics maturity, digital literacy, leadership commitment, organizational culture, and governance mechanisms. However, much of the literature examines these factors independently and provides limited explanation for why organizations with similar technology investments often achieve substantially different outcomes. Emerging evidence suggests that the ability to generate

value from digital technologies depends not only on technological capability but also on the maturity of organizational information systems, data governance practices, information quality, and the extent to which information is trusted and utilized throughout the organization. Consequently, organizational information maturity may represent a critical yet underexplored capability influencing HR digitalization success.

To address this gap, this study develops the HR Digitalization Success Matrix, a conceptual framework that integrates Organizational Information Maturity and HR Digitalization Success into a single classification model. Drawing upon digital maturity literature, HR analytics research, information governance studies, and organizational capability theories, the framework proposes that sustainable HR digital transformation emerges through the simultaneous development of information maturity and digital capability. By positioning organizations according to these two dimensions, the HDSM provides a theoretical lens for understanding digital transformation outcomes and offers practitioners a structured approach for assessing organizational maturity and identifying pathways toward strategic digital HR transformation.

2 LITERATURE REVIEW

2.1 *Organizational Information Maturity and HR Digitalization Success*

Digital transformation in human resource management increasingly depends on the maturity of organizational information systems, data governance practices, leadership engagement, and the ability of HR functions to move from administrative digitalization toward strategic, data-driven decision-making. Digital maturity in HRM is therefore not limited to the adoption of HR technologies; rather, it reflects the organization's capacity to integrate digital tools, information flows, human resource processes, and managerial decision practices into a coherent transformation pathway. Nazarova and Rudenko [1] argue that digital maturity enables organizations to adapt to change and strengthen HR strategies, thereby improving the success of digital transformation initiatives.

Prior research also suggests that information maturity plays a direct role in improving the effectiveness of advanced digital applications in HRM. SadrJahani, Moghaddam, and Zarei [2] found that information maturity significantly influences perceptions of artificial intelligence effectiveness in HRM, indicating that organizations with stronger data collection, processing, and usage capabilities are better positioned to benefit from AI-enabled HR practices. Similarly, Turulja and Bajgoric [3] demonstrate that information technology capability, knowledge management capability, and HRM capability interact positively to enhance organizational performance. The maturity perspective is also supported by studies on HR service digitalization and technology implementation. Ketolainen [4] emphasizes that organizations must first understand their HR maturity and HR service maturity before selecting appropriate digital operating models and service delivery mechanisms. This is particularly important because low levels of HR service maturity can weaken the value created through automation and data-driven HR systems. In a related maturity-model perspective, Tripathi et al. [5] show that successful technology implementation depends on sufficient maturity across people, processes, and technology, with lower maturity levels increasing the likelihood of implementation failure.

Digital governance research further supports the relationship between maturity HRM effectiveness and service outcomes. Sulaiman et al. [6] found that digital governance strengthens the relationship between work culture, HR management and public satisfaction suggesting that digital systems become more effective when supported by mature governance structures and organizational culture.

2.2 *Factors Influencing HR Digitalization Success*

Existing literature suggests that HR digitalization success is influenced by a combination of technological, organizational, human and environmental factors while organizations increasingly invest in Human Resource Information Systems, Human Resource Analytics, Artificial Intelligence, and digital platforms the effectiveness of these investments depends on the maturity of supporting organizational capabilities.

Digital maturity research highlights the importance of system integration, infor-

mation connectivity, and continuous skill development in achieving sustainable digital transformation. Nazarova and Rudenko [1] argue that digitally mature HR functions are characterized by seamless integration across HR systems, enabling efficient information exchange and supporting data-driven decision-making. The authors further emphasize that continuous learning and employee skill development are critical prerequisites for maintaining digital maturity in dynamic organizational environments. From a technology implementation perspective, Gabriel et al. [7] identify human, technological, organizational, and environmental factors as critical success factors for digital transformation within human capital information systems. Findings indicate that environmental readiness, human capabilities, technological infrastructure, and organizational support collectively determine the success of digital data integration initiatives. These findings are consistent with broader digital transformation literature, which views transformation success as an interaction between technological resources and organizational capabilities.

Human resource capabilities also play a central role in organizational digitalization efforts. Khamiliyah et al. [8] identify data literacy, collaborative capability, and digital trust as strategic human resource factors that contribute to the development of digital culture and organizational readiness. These factors strengthen employee's ability to engage with digital systems and facilitate the transition toward data-driven organizational practices. Data quality and analytics capability represent additional determinants of HR digitalization success. Dahlbom et al. [9] report that poor data quality, inadequate analytical skills, and traditional information systems frequently prevent organizations from advancing beyond basic reporting functions. Furthermore, compliance-oriented organizational cultures often limit the development of advanced analytics capabilities. Similar findings are reported by Ozkanli and Gök [10], who identify strategic alignment, technological capability, and data capability as fundamental dimensions of HR analytics maturity.

Technology acceptance factors continue to influence HR digitalization outcomes. Amoako et al. [11] demonstrate that perceived usefulness, perceived ease of use, and compatibility significantly affect e-HRM implementation intentions. These findings support the Technology Acceptance Model (TAM), suggesting that successful HR digitalization requires alignment between organizational processes and digital technologies. Recent studies further emphasize the role of digital literacy and analytics maturity. Jimoh [12] found that employee digital literacy significantly mediates the relationship between digital HR system adoption and administrative efficiency. Similarly, Ioakeimidou et al. [13] identify organizational Analytics Maturity (OAM) as one of the strongest predictors of human resource analytics adoption, with information technology infrastructure, HR capabilities, and top management support serving as major contributors to maturity development. A maturity-based perspective is further reinforced by Rigamonti et al. [14], who conceptualize HR analytics maturity through technological, organizational, functional, and diffusion dimensions.

Collectively, these studies indicate that HR digitalization success is multidimensional and dependent upon the interaction of information quality, data governance, digital literacy, leadership commitment, analytics capability, technology acceptance, organizational culture, and system integration. These factors provide the theoretical foundation for the HR Digitalization Success Matrix and support the proposition that higher levels of organizational information maturity are associated with greater HR digitalization success.

2.3 *Maturity Typologies and Classification Models in Digital HRM*

Digital HRM literature increasingly recognizes that organizations do not progress through digital transformation in a uniform manner. Instead, they differ according to maturity levels, digital strategy, operational adoption, information capability, analytics capacity, and human readiness. This supports the need for classification models that can differentiate organizations based on their level of HR digitalization success and organizational information maturity.

Shahiduzzaman [15] identifies three major themes shaping HR digital maturity in the post-COVID era: digital transformation and competition, innovation and performance management, and adaptive HRM. This indicates that HR digital maturity is

multidimensional and includes technological, human, innovation, and crisis-response capabilities. Similarly, Zavyalova et al. [16] distinguish between quantitative and qualitative dimensions of HR digitalization, showing that digitalization must be assessed not only by the breadth of technology use but also by the effectiveness and strategic value of digital practices. Maturity-stage approaches further support the development of the HR Digitalization Success Matrix. Som and Gamroth [17] propose five stages for assessing HRM digital maturity, while Rigamonti et al. [14] develop an HR analytics maturity model consisting of technological, organizational, functional, and diffusion dimensions. These models suggest that organizations can be positioned along progressive maturity pathways, moving from basic adoption toward strategic and data-driven HR capability.

Strohmeier [18] develops a typology of digital HRM based on the digitalization of HR strategies and practices. Gudergan et al. [19] distinguish between digitally developing and digitally mature organizations using maturity-level logic, while Becker et al. (2025) apply cluster-based classification to identify high, medium and low digital maturity groups. The literature also highlights the importance of human and organizational factors in maturity classification. Kaszás et al. [20] show that learning organization characteristics are associated with higher digital maturity, while Hajiyev [21] identifies behavioral digitalization clusters based on strategic mindset, adoption, and performance. Angelova et al. (2026) further show that organizations differ in digital HR tool adoption according to training investment and senior management engagement.

3 FRAMEWORK DEVELOPMENT METHODOLOGY

3.1 *Research Design*

This study adopts a conceptual framework development approach to construct the HR Digitalization Success Matrix. The framework was developed through the integration of three complementary sources of knowledge: academic literature, practitioner insights and longitudinal professional experience. This approach is consistent with conceptual model development studies that seek to synthesize existing knowledge and translate theoretical insights into practical classification frameworks.

3.2 *Literature Review and Concept Extraction*

The first stage involved a structured review of the literature relating to human resource digitalization, digital maturity, organizational information maturity, HR analytics maturity, digital governance, data-driven decision-making and digital transformation. Approximately fifty academic publications were examined to identify recurring constructs, maturity dimensions, success factors, and classification approaches relevant to HR digitalization and organizational information maturity.

The reviewed literature included studies on HR digital maturity, organizational analytics maturity, digital governance, technology acceptance, HR analytics capability, information quality, data governance, leadership engagement, and digital transformation success. Attention was given to maturity models and organizational classification frameworks that differentiate organizations according to levels of digital capability and information utilization.

The literature review resulted in the identification of two dominant conceptual domains: (1) Organizational Information Maturity and (2) HR Digitalization Success. These domains subsequently formed the foundation of the proposed matrix.

3.3 *Practitioner Interviews*

To complement the literature findings, semi-structured discussions were conducted with organizational clients involved in HR digital transformation initiatives. The purpose of these discussions was to understand practical challenges associated with HRIS implementation, data quality management, analytics adoption, organizational readiness, leadership engagement, and digital decision-making practices.

The interviews were not intended to generate statistically generalizable findings. Rather, they served as a source of practitioner validation, enabling the researchers to compare theoretical constructs with observed organizational realities and identify recurring patterns across implementation environments.

Insights obtained from these discussions informed the development of the quadrant definitions, maturity progression pathways, and organizational characteristics represented within the proposed framework.

3.4 *Experience Mapping and Longitudinal Observation*

The third stage involved experience mapping based on more than fifteen years of professional involvement in HR digital transformation projects across multiple organizations. Experience mapping refers to the systematic reflection and abstraction of recurring organizational patterns observed during digital transformation initiatives.

Over this period, organizations exhibited varying levels of information maturity, system adoption, data governance capability, leadership commitment, analytics utilization and HR digitalization outcomes. These observations enabled the identification of common organizational profiles and transition pathways between maturity states.

The longitudinal perspective provided an opportunity to observe how organizations evolved over time and how differences in information maturity influenced the success or failure of HR digitalization initiatives.

3.5 *Framework Development Process*

The HR Digitalization Success Matrix was developed through an iterative synthesis process consisting of four stages:

1. Identification of maturity-related constructs from the literature.
2. Validation of practical relevance through practitioner interviews.
3. Pattern recognition through longitudinal experience mapping.
4. Integration of theoretical and practitioner perspectives into a two-dimensional classification framework.

The resulting matrix positions organizations according to their level of Organizational Information Maturity and HR Digitalization Success, producing four conceptual organizational categories and associated maturity progression pathways.

3.6 *Ethical Considerations*

The study does not report individual-level personal data, confidential organizational information, or sensitive employee records. Practitioner discussions were used solely for conceptual model development and organizational pattern identification. No identifiable organizational information is disclosed within this paper.

3.7 *Use of Artificial Intelligence*

Generative Artificial Intelligence (GenAI) tools were used to support language refinement, conceptual organization, and manuscript preparation. All theoretical interpretations, framework development decisions, literature synthesis, practitioner insights, and final academic content were reviewed and validated by the author. No empirical data, findings, or citations were generated by artificial intelligence.

4 RESULTS

The HR Digitalization Success Matrix was used to assess the interaction between Organizational Information Maturity and HR Digitalization Success. The matrix positions organizations according to their level of information maturity and their success in leveraging digital technologies for HR decision-making and strategic contribution. The distribution of organizations across the matrix reveals substantial differences in digital transformation outcomes despite similarities in technology adoption.

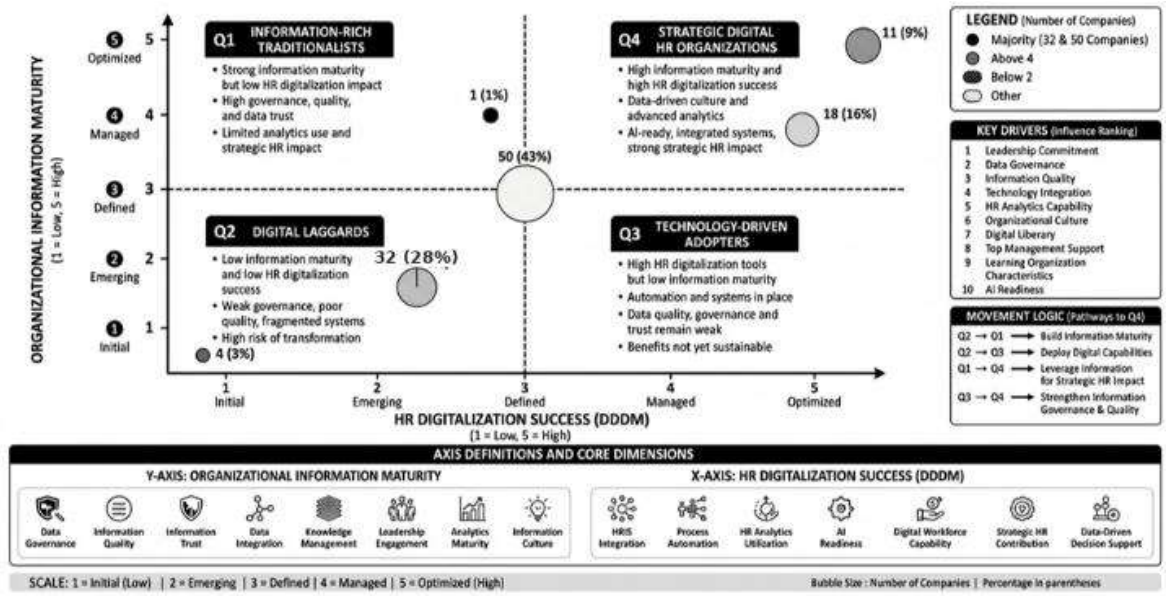


Figure 1. HR digitalization success matrix

Table 1. HR digitalization success matrix data sheet

Position	Organizations	Percentage
Q4 Strategic Digital HR Organizations (16% + 9%)	29	25%
Q1 Transitional Zone (Score 3,3)	50	43%
Q1 Information-Rich Traditionalists	1	1%
Q2 Digital Laggards	4	3%
Q2 Emerging Maturity Zone (Score 2,2)	32	28%
Q3 Technology-Driven Adopters	0	0%

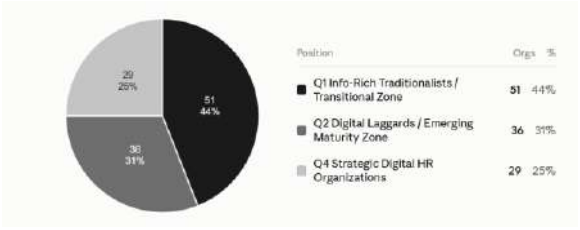


Figure 2. Distribution of organizations across the HR digitalization success matrix

The results indicate that organizations are concentrated primarily in the middle stages of maturity. The largest group, representing 43% of organizations, is located at the intersection of Organizational Information Maturity Level 3 and HR Digitalization Success Level 3. A further 28% of organizations are positioned within the emerging maturity zone at Level 2 on both dimensions. Together, these findings suggest that most organizations have moved beyond the initial stages of digitalization but have not yet achieved strategic digital maturity.

The Digital Laggards category contains only four organizations, representing 3% of the sample. These organizations demonstrate low levels of information maturity and low levels of HR digitalization success. Their position suggests that digital transformation remains limited by poor information quality, weak governance mechanisms, fragmented systems, and insufficient digital capabilities. In these environments, HR decisions are largely operational and often depend on manual processes and individual experience rather than reliable organizational information.

The *Emerging Maturity* represents organizations that have begun implementing digital HR practices but continue to face significant limitations in governance, information quality, and organizational readiness. Although foundational technologies such as HRIS platforms may be present, their contribution to strategic decision-making remains limited. This cluster appears to represent organizations transitioning from basic automation toward more integrated forms of digital HR management.

The largest concentration of organizations is found in the Transitional Zone. Fifty organizations, accounting for 43% of the sample, occupy the midpoint of both dimensions. These organizations generally possess operational HR systems, standardized processes, and moderate levels of information maturity. However, they have not yet fully embedded analytics, governance, or data-driven culture into organizational decision-making. The dominance of this cluster suggests that many organizations successfully

implement digital technologies but encounter difficulties transforming digital data into strategic organizational intelligence. This finding supports arguments within the digital transformation literature that technology implementation alone is insufficient to generate sustainable transformation outcomes.

Only one organization was positioned within the *Information-Rich Traditionalists* quadrant. This organization demonstrates relatively high levels of information maturity but comparatively low levels of HR digitalization success. The presence of this category suggests that strong governance, reliable information, and effective data management do not automatically translate into digital transformation success. Instead, organizations must also develop analytical capability, strategic HR participation, and effective utilization of information resources. This quadrant illustrates that information maturity is a necessary but not sufficient condition for successful HR digitalization. *The Strategic Digital HR Organizations* quadrant contains twenty-nine organizations, representing approximately one-quarter of the sample. This group includes organizations positioned at both maturity level four and maturity level five. These organizations demonstrate strong information governance, high-quality data, integrated HR systems, advanced analytics capability, and active leadership engagement. Their position indicates that successful HR digitalization occurs when technological capability evolves together with information maturity. *In these organizations, HR functions move beyond administrative support and contribute directly to strategic planning, workforce intelligence, and organizational performance*.

A notable observation is the absence of a substantial population within the *Technology-Driven Adopters* quadrant. Theoretical expectations suggest that organizations may invest heavily in digital technologies without developing corresponding information maturity. However, the *limited representation of this category implies that sustained HR digitalization success may be difficult to achieve when governance structures, information quality, and organizational trust in data remain weak*. This observation reinforces arguments from information maturity and digital governance research that information capability serves as a foundational condition for long-term digital transformation success.

Overall, the results suggest that organizational information maturity and HR digitalization success are closely interconnected. Organizations occupying higher maturity levels tend to demonstrate stronger governance, higher-quality information, greater analytical capability, and more effective utilization of digital technologies. Conversely, organizations with weaker information maturity appear less capable of realizing the strategic benefits of digital HR investments. The findings therefore support the central proposition of the HR Digitalization Success Matrix: sustainable HR digital transformation is achieved not through technology adoption alone but through the simultaneous development of information maturity, governance capability, leadership commitment, and data-driven organizational culture.

5 DISCUSSION

The HR Digitalization Success Matrix demonstrates that successful HR digital transformation depends on the interaction between Organizational Information Maturity and HR Digitalization Success. The findings suggest that technology adoption alone is insufficient to achieve sustainable transformation outcomes. Instead, organizations must develop strong information governance, data quality, analytics capability, leadership engagement, and information culture alongside digital technologies. The dominance of organizations within the transitional and emerging maturity zones indicates that many *organizations have implemented HR technologies but have not yet converted these investments into strategic organizational capabilities*. This observation supports digital maturity literature, which argues that transformation occurs through progressive capability development rather than isolated technology implementation initiatives. A particularly important finding is the near absence of organizations within the Technology-Driven Adopters quadrant. This suggests that organizations struggle to sustain high levels of HR digitalization when information maturity remains weak. The finding supports the Resource-Based View and Dynamic Capabilities Theory by indicating that information quality, governance structures, and analytics capabilities func-

tion as strategic organizational resources that enable digital transformation success. The framework also extends existing HR digitalization literature by introducing Organizational Information Maturity as a central explanatory construct. The HDSM suggests that information maturity serves as the foundation upon which HR analytics, AI readiness, digital workforce capability, and strategic HR contribution can be developed. Consequently, organizations seeking digital transformation should invest not only in technologies but also in strengthening their information ecosystems.

6 CONCLUSION

This study developed the HR Digitalization Success Matrix, a conceptual framework that explains HR digital transformation through the interaction between Organizational Information Maturity and HR Digitalization Success. Drawing upon digital maturity, HR analytics, digital governance, and organizational capability literature, the framework proposes that *successful transformation is achieved through the simultaneous development of information maturity and digital capability*. The framework contributes to theory by positioning Organizational Information Maturity as a foundational capability influencing digital transformation outcomes. *It also contributes to practice by providing organizations with a diagnostic tool for identifying their maturity position and guiding progression toward higher levels of digital transformation*. Although the framework is grounded in literature, practitioner insights, and longitudinal experience, it remains conceptual. Future research should develop measurement instruments, validate the proposed dimensions empirically, and examine the relationship between maturity levels and organizational performance outcomes. The HDSM provides a foundation for future research and offers a practical roadmap for organizations seeking to achieve sustainable HR digital transformation.

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The Role of Multilateral Climate Funds in Shaping the Architecture of Climate Finance: An Analysis of Blended Finance and Institutional Collaboration among MDBs, Central Banks, and Private Capital across the G77 and China

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ABSTRACT: The transition to a low-carbon global economy is constrained by a persistent climate finance gap across the G77 and China. This study examines how Multilateral Climate Funds shape climate finance architecture through four determinants: institutional collaboration, blended finance deployment, policy and regulatory alignment, and transparency. Combining survey data from 103 sustainable finance specialists with eight semi-structured expert interviews, the study finds that institutional collaboration is the only determinant with a statistically significant independent association with perceived architecture effectiveness. Blended finance shows a significant bivariate association and remains the principal qualitative mechanism for mobilising private capital, although its independent regression effect is not statistically significant. Policy and regulatory alignment is viewed as necessary for domestic capital absorption, while transparency supports investor trust and reduces greenwashing concerns, despite neither variable reaching statistical significance in the survey. The study therefore distinguishes statistically supported relationships from practitioner perceptions and introduces an Institutional Reinforcement Cycle as a conceptual, recursive model of how institutional, financial, regulatory, and transparency conditions may reinforce one another over time. The findings support practical reforms centred on coordinated MCF-MDB platforms, faster risk-sharing instruments, stronger domestic regulatory integration, and standardised impact reporting, while recognising the limits of a cross-sectional, perception-based sample. The model is presented as a proposition for future calibration rather than as validated dynamic system.

Keywords: climate finance, multilateral climate funds, blended finance, multilateral development banks, institutional collaboration

1 INTRODUCTION

The global financial system is undergoing a critical transformation as the urgency of addressing climate change escalates. The international community has increasingly emphasised sustainable and inclusive financial systems through the UNFCCC Paris Agreement, the Sustainable Development Goals, and the Belém Political Package at UNFCCC COP30 in 2025. Central banks, private capital and Multilateral Development Banks (MDBs) have an important role in facilitating green finance and supporting the transition beyond 2050 [10]. This question is particularly important for countries within the G77 and China that are highly exposed to climate shocks, debt pressures and constraints on domestic investment capacity.

Despite the expansion of Multilateral Climate Funds (MCFs), the literature remains fragmented across individual funds and instruments. Less attention has been given to the way institutional collaboration, blended finance deployment, domestic regulatory alignment, and transparency operate

together as an institutional system. Existing research identifies persistent transaction costs, fragmented mandates and uneven access, but the interaction among these conditions remains insufficiently integrated [6], [14], [21]. This study addresses that gap by examining how the four determinants relate to the operational architecture of MCFs, while using expert interviews to explain the institutional mechanisms behind the survey evidence.

1. Research Question (RQ1): What is the influence of institutional collaboration, the effectiveness of blended finance deployment, policy and regulatory alignment, and transparency and accountability of fund utilisation in the operational architecture of multilateral climate funds, across the G77 and China?
2. Research Aim (RA1): To evaluate the role of MCFs in shaping climate finance architecture and provide recommendations to countries and MDBs, with particular focus on how collaboration among MDBs, private capital and central banks influences fund utilisation, effectiveness and governance.
3. Research Objectives: RO1 identifies the influence of institutional collaboration; RO2 evaluates the influence of blended finance deployment; RO3 examines policy and regulatory alignment; and RO4 determines the influence of transparency and accountability on the operational architecture of MCFs.

2 LITERATURE REVIEW

The architecture of climate finance has evolved from the post-war logic of Official Development Assistance (ODA) towards a broader framework of global public goods. The 2030 Agenda, Addis Ababa Action Agenda and Paris Agreement reinforced this transition, placing mitigation, adaptation and disaster-risk reduction closer to the centre of development finance [5], [27]. At the same time, the financing requirement has moved from billions towards trillions, with estimates indicating that EMDEs excluding China require roughly USD 1–2.4 trillion annually by 2030 to meet climate and development objectives [5]. This scale of need has intensified attention to mechanisms capable of mobilising private investment.

MCFs such as the Green Climate Fund (GCF), Global Environment Facility (GEF) and Climate Investment Funds (CIF) sit within a wider and increasingly complex architecture involving MDBs and other financial institutions. The literature identifies fragmentation, bureaucratic procedures and high transaction costs as persistent barriers to effective deployment [14]. Institutional design is therefore important for legitimacy and for operational effectiveness. Concerns regarding representation and power asymmetry have also encouraged demands for greater voice for developing countries and stronger South-South institutional cooperation [8], [26].

MDBs increasingly operate as catalytic agents capable of linking public policy with private capital. However, risk aversion and bureaucratic procedures can delay climate investment, particularly where projects require concessional instruments, guarantees or complex approvals [21]. The literature consequently emphasises the need to integrate climate risk into financial and macro-fiscal frameworks and to use policy-based instruments to reduce perceived risk [10], [16]. For vulnerable economies, conventional creditworthiness measures may also fail to capture climate vulnerability and development constraints [24], [25].

Blended finance is central to this debate because public or multilateral resources can be used to de-risk projects and mobilise private capital [9], [22]. Yet capital availability alone does not determine impact: the choice of financial instruments, the speed of deployment and the surrounding governance arrangements affect whether investment can be translated into sustainable outcomes [11], [15]. Standardised reporting and carbon-accounting approaches can strengthen confidence, while weak alignment and fragmented implementation can limit access for SIDS and other vulnerable members of the G77 [9], [25].

The literature therefore supports a framework built around four linked pillars: institutional collaboration, blended finance deployment, policy and regulatory alignment, and transparency and accountability. The present study uses this framework to distinguish between what practitioners value conceptually and what is statistically associated with perceived architecture effectiveness.

The institutional dimension of climate finance is inseparable from questions of legitimacy and operational control. Research on multilateralism highlights geopolitical fragmentation and declining confidence in established institutions [8]. Within the G77 and China, demands for a fairer international financial architecture reflect concerns over representation, voting power and the distribution of decision-making authority [26]. These concerns matter operationally because climate funds often depend on accredited entities and intermediary institutions to convert board-level decisions into projects.

The proliferation of vertical funds alongside MDB climate windows creates a multilayered system in which similar objectives can be pursued through different rules, approval processes and reporting requirements. Such complexity can increase transaction costs and weaken country ownership [14]. National and regional mechanisms can partly counter these constraints by providing greater alignment with domestic priorities, while South-South institutions offer additional channels for cooperation [8].

The role of MCFs is consequently broader than the transfer of resources. Their effectiveness depends on whether they can coordinate financial instruments, institutional mandates and domestic policy environments. Concessional loans, equity, guarantees and blended structures can reduce risk, but their impact depends on how quickly and predictably they are deployed [11], [15]. This supports a shift in analytical focus from capital volume alone toward the architecture through which capital is mobilised and absorbed.

The four-pillar framework used in this study follows this literature. Institutional collaboration captures coordination among MCFs, MDBs, central banks and private capital. Blended finance deployment captures the practical use of concessional and risk-sharing instruments. Policy and regulatory alignment captures the domestic conditions that permit climate finance to enter and circulate within financial systems. Transparency and accountability capture the information and monitoring conditions that support credibility and investor confidence.

3 RESEARCH METHODOLOGY

This study adopted a mixed-methods design. Eight semi-structured depth interviews with representatives from MDBs, central banking and regulatory bodies, private capital and MCF operations formed the qualitative strand, supported by a cross-sectional survey of 103 sustainable-finance specialists. The research followed a Case Study Survey strategy, examining a contemporary phenomenon within its institutional context [18]. Data were collected at a single point in time, allowing patterns among institutional, financial and regulatory variables to be examined [19].

The qualitative component was purposively sampled to obtain high-level professional expertise. Each interview lasted approximately 45–60 minutes and was recorded with prior consent. Given the small expert sample, the qualitative component is treated in this final version as exploratory expert elicitation rather than as evidence of population saturation. The analysis involved transcription, identification of recurring patterns and thematic content analysis. The three dominant themes were Fragmented Governance and Institutional Silos; The Catalytic Limits of Blended Finance; and Regulatory Dissonance in Emerging Markets.

The survey questionnaire was developed in English and distributed digitally through Microsoft Forms. A sample of 103 respondents was drawn from a population of 144 sustainable-finance specialists across the G77 and China, covering MDBs, central banks and regulatory bodies, and private-capital or ESG stakeholders. The sample comprised 77 respondents associated with G77 nations and 26 associated with China. The sectoral distribution was 45 MDB respondents, 30 central-bank or regulatory respondents, and 28 private-capital or ESG respondents. These data provide practitioner evidence rather than a statistically representative census of the G77 and China.

Table 1. Quantitative sample distribution by sector and region

Sector	G77 Nations	China	Total
MDBs	35	10	45
Central Banks & Regulatory Bodies	22	8	30
Private Capital Stakeholders	20	8	28
Total	77	26	103

Source: Author

Internal consistency was assessed for each composite scale using Cronbach's alpha prior to composite-variable creation. All five scales exceeded the 0.70 threshold: Institutional Collaboration (7 items, $\alpha = .829$), Blended Finance Deployment (7 items, $\alpha = .823$), Policy and Regulatory Alignment (7 items, $\alpha = .813$), Transparency and Accountability (7 items, $\alpha = .846$), and Climate Finance Architecture (4 items, $\alpha = .863$); standardised alphas were consistent with these values (see Table 2). Content validity was supported through the literature review and expert consultation.

Table 2. Scale reliability (Cronbach's alpha)

Construct / Scale	Items (N)	Cronbach's Alpha (α)	Standardised Alpha
Institutional Collaboration (IC)	7	.829	.825
Blended Finance Deployment (BFD)	7	.823	.822
Policy and Regulatory Alignment (PRA)	7	.813	.814
Transparency and Accountability (TAFU)	7	.846	.847
Climate Finance Architecture (CFA)	4	.863	.864

Source: Author

Construct dimensionality was checked using principal axis factoring with Promax rotation across all 32 items. Sampling adequacy was acceptable (KMO = .667) and Bartlett's test of sphericity was significant ($\chi^2 = 1546.543$, $df = 496$, $p < .001$), confirming that the correlation matrix was suitable for factor analysis. Five factors were extracted on an eigenvalue-greater-than-1 criterion, matching the five hypothesised composites and jointly explaining 47.51% of the cumulative rotated variance. This factor structure offers preliminary support for the distinctiveness of the five constructs; item-level factor loadings and formal discriminant-validity indices are not reported here and would be needed before construct validity can be treated as fully established.

Survey responses were measured on a five-point Likert scale and summarised using means, standard deviations and tests of normality. Pearson correlation and multiple regression were used to examine bivariate association and the independent contribution of the four constructs. The final manuscript does not report numerical Spearman's rho or Kendall's tau-b results; those tests are therefore not presented as evidence. Multicollinearity was assessed using tolerance and variance inflation factor statistics, and autocorrelation in the regression residuals was assessed using the Durbin-Watson statistic; both are reported in Section 4.2. A full set of residual plots is not reproduced in the manuscript text. Accordingly, the results are interpreted as associations within a cross-sectional perception-based sample rather than as causal effects.

3.1 *Survey constructs and propositions*

Table 3. Survey constructs and propositions

Construct	Proposition
Institutional Collaboration (IV1)	Institutional collaboration is associated with the operational architecture of MCFs.
Blended Finance Deployment (IV2)	The effectiveness of blended finance deployment is associated with the operational architecture of MCFs.
Policy & Regulatory Alignment (IV3)	Policy and regulatory alignment is associated with the operational architecture of MCFs.
Transparency & Accountability (IV4)	Transparency and accountability of fund utilisation is associated with the operational architecture of MCFs.
Climate Finance Architecture (DV)	Perceived effectiveness/ coherence of the operational architecture of MCFs.

Source: Author

3.2 *Analytical approach and hypothesis testing*

The quantitative strand was designed to provide breadth and a structured test of relationships among the five composite constructs. Pearson correlation was used to examine bivariate association, followed by multiple regression to identify whether each independent variable retained an association

after the other constructs were considered. The qualitative strand was analysed thematically and used to explain the institutional mechanisms suggested by the survey results.

In particular, this study does not describe the coefficient of determination as a validity test, and does not report non-parametric coefficients for which numerical results are unavailable. It does report the exploratory factor analysis results available from the final analysis, including the KMO and Bartlett statistics and the cumulative variance explained, but stops short of claiming item-level factor loadings or discriminant-validity indices that were not produced. These changes improve transparency and prevent unsupported statistical interpretation.

3.3 *Qualitative integration*

The interview findings were integrated with the survey at the interpretation stage. The interviews were used to identify mechanisms that could help explain why a construct was or was not associated with perceived architecture effectiveness, not to force qualitative themes into statistical confirmation. The eight interviews are therefore positioned as exploratory expert evidence, with the small purposive sample treated as a limitation on saturation and generalisability.

4 FINDINGS AND ANALYSIS

4.1 *Analysis of depth interviews*

The interviews provide context for these quantitative patterns. Theme 1, Fragmented Governance and Institutional Silos, captures recurring concerns about overlapping mandates, disparate deployment criteria, duplication and transaction costs. Theme 2, The Catalytic Limits of Blended Finance, highlights the gap between theoretically attractive concessional and risk-sharing instruments and the time required to secure them. Theme 3, Regulatory Dissonance in Emerging Markets, emphasises the importance of domestic financial rules and central-bank integration for absorbing external climate finance.

Table 4. Thematic matrix of qualitative findings and variable mapping

Dominant Theme	Operational Concepts & Codes	Mapped Variables
Fragmented Governance and Institutional Silos	Vertical fund–MDB friction; bureaucratic inertia; strategic alignment failure; duplication; high transaction costs	IV1 Institutional Collaboration; IV4 Transparency & Accountability; DV Climate Finance Architecture
The Catalytic Limits of Blended Finance	Operational friction; concessional-finance inefficiency; time-lag disincentive; private-capital mobility; over-centralised approvals	IV2 Blended Finance Deployment; IV4 Transparency & Accountability; DV Climate Finance Architecture
Regulatory Dissonance in Emerging Markets	Domestic policy preconditions; macro-fiscal integration; prudential policy adjustments; isolated pilots; systemic absorption barriers	IV3 Policy & Regulatory Alignment; DV Climate Finance Architecture

Source: Author

IV4 is mapped to Theme 1 as a secondary governance variable because fragmentation affects information flows, accountability and the visibility of how funds are allocated; the mapping does not mean that transparency was independently tested within that qualitative theme. Similarly, IV4 appears alongside IV2 in Theme 2 because reporting and monitoring conditions shape confidence in blended-finance deployment. The thematic matrix therefore indicates conceptual overlap rather than separate statistical tests.

4.2 *Survey analysis*

The reliability analysis produced Cronbach's alpha values between 0.813 and 0.863 across the five composite scales. Descriptively, respondents reported relatively positive views of the four proposed determinants, while their assessment of the existing climate finance architecture was more moderate. Institutional collaboration included strong agreement that partnerships between MCFs and private capital improve access to finance (Mean = 3.89, SD = 0.766) and that central-bank engagement is important (Mean = 3.96). The statement concerning reduced duplication recorded the highest IV1 mean (4.52, SD = 0.654).

For blended finance deployment, risk-sharing mechanisms and the ability of blended structures to mobilise private capital received means of 3.84 and 3.82, respectively. Lower scores for the operational design and co-financing arrangements between MDBs and private capital (3.33 and 3.35) indicate a distinction between the perceived value of blended finance and the practical

experience of deployment. Policy and regulatory alignment also showed a gap between principle and implementation: clear regulatory standards improving transparency recorded a mean of 4.01, whereas the view that current G77 regulatory frameworks facilitate integration recorded 3.23 (SD = 0.992).

Transparency and accountability recorded means of 3.81 and 3.85 for reporting and utilisation items. Respondents therefore placed substantial value on standardised impact measurement and accountability. The dependent variable was less strongly rated: the statement that the current institutional structure promotes coherence between public and private climate finance actors recorded a mean of 3.44 (SD = 0.825), while perceived coherence of the current institutional design was 3.46. This contrast is central to the study: the enabling conditions were valued more highly than the perceived performance of the architecture in which they operate.

At the composite level, scale means ranged from 3.53 (Blended Finance Deployment and Policy and Regulatory Alignment) to 3.81 (Institutional Collaboration), with standard deviations between 0.52 and 0.73 (Table 5). Shapiro-Wilk tests indicated significant departures from normality for Institutional Collaboration, Blended Finance Deployment, Transparency and Accountability, and Climate Finance Architecture ($p \leq .003$), while Policy and Regulatory Alignment did not differ significantly from a normal distribution ($p = .149$). Skewness and kurtosis values remained moderate throughout (skewness between −0.86 and 0.41; kurtosis between −0.34 and 1.70). Given the sample size (N = 103) and the general robustness of ordinary least squares regression to moderate non-normality, the parametric analyses below are retained, while this departure from normality is noted as a limit on the precision of the reported inferential statistics.

Table 5. Descriptive statistics and tests of normality (N = 103)

Variable	Mean	SD	Median	Skewness	Kurtosis	Shapiro-Wilk p
Institutional Collaboration	3.810	.553	3.857	−.763	.916	< .001
Blended Finance Deployment	3.530	.521	3.429	.411	−.247	.003
Policy and Regulatory Alignment	3.531	.626	3.571	−.038	−.335	.149
Transparency and Accountability	3.735	.574	3.714	−.855	1.700	< .001
Climate Finance Architecture (DV)	3.570	.730	3.750	−.516	.513	.003

Source: Author

Table 6 reports the full regression model. Institutional collaboration had a positive and statistically significant Pearson correlation with perceived architecture effectiveness ($r = .409$, $p < .001$) and remained the only significant independent predictor in the multiple regression ($B = .515$, $SE = .122$, $\beta = .390$, $t = 4.218$, $p < .001$). Blended finance had a significant bivariate association ($r = .214$, $p = .030$), but its independent regression coefficient was not significant ($B = .169$, $SE = .130$, $\beta = .121$, $t = 1.303$, $p = .196$). Policy and regulatory alignment was not significant in either analysis ($r = −.005$, $p = .958$; $B = .028$, $SE = .106$, $\beta = .024$, $t = .263$, $p = .793$). Transparency was positive but not significant ($r = .150$, $p = .132$; $B = .185$, $SE = .115$, $\beta = .145$, $t = 1.607$, $p = .111$). The overall model was statistically significant, $F(4, 98) = 6.388$, $p < .001$, accounting for 20.7% of the variance in Climate Finance Architecture ($R^2 = .207$, adjusted $R^2 = .174$; standard error of the estimate = .663). The Durbin-Watson statistic (1.797) indicated no evidence of first-order autocorrelation in the residuals, and collinearity diagnostics showed no multicollinearity concern (tolerance .940–.987; VIF 1.013–1.064 across predictors).

Table 6. Regression coefficients and collinearity statistics

Predictor	B	SE	β	t	p	VIF
(Constant)	222	809	-	.275	.784	-
Institutional Collaboration	515	122	.390	4.218	<.001	1.055
Blended Finance Deployment	169	130	.121	1.303	.196	1.064
Policy and Regulatory Alignment	028	106	.024	.263	.793	1.021
Transparency and Accountability	185	115	145	1.607	.111	1.013

Source: Author

Table 7 restates these results against each hypothesis. Full regression diagnostics (standard errors, t-values, the model F-test, R^2 and adjusted R^2, and collinearity statistics) are reported alongside the coefficients in Table 6 above.

Table 7. Hypothesis testing summary

Hypothesis	Pearson r	p	β	p	Interpretation
Institutional Collaboration (H1)	.409	< .001	.390	< .001	Supported association; strongest independent result
Blended Finance Deployment(H2)	.214	.030	.121	.196	Bivariate association supported; independent effect not significant
Policy & Regulatory Alignment (H3)	−.005	.958	.024	.793	No statistically significant association in available analysis
Transparency & Accountability (H4)	.150	.132	.145	.111	Positive direction, but not statistically significant

Source: Author

The hypothesis narrative remains conservative, so that statistical significance is not inferred from the direction of a relationship alone. H1 is the only hypothesis with evidence of an independent association in the regression results. H2 has a significant bivariate association but not a significant regression coefficient. H3 and H4 are not statistically significant on the reported measures.

4.3 *Discussion of findings*

The strongest quantitative result concerns institutional collaboration. The positive association suggests that respondents who perceive stronger coordination among MCFs, MDBs, central banks and private actors also tend to perceive a more effective climate finance architecture. The interviews reinforce this interpretation by describing fragmented mandates and internal risk procedures as operational barriers. This does not mean collaboration causes effectiveness. It means coordination is a central institutional condition associated with perceived architecture performance. Regional MDBs may therefore have a useful catalytic role where project-level knowledge can complement central fund governance.

Blended finance presents a more nuanced result. Its bivariate relationship with architecture effectiveness is statistically significant, but the regression coefficient is not significant after accounting for the other constructs. This does not negate its importance in the interviews: participants consistently described guarantees, concessional finance and risk-sharing as important mechanisms for crowding in private capital. Rather, the evidence suggests that the effectiveness of blended finance may depend on the institutional environment in which those instruments are deployed. Slow approval processes and bespoke structures can weaken the practical catalytic effect even when the underlying instruments are attractive.

Policy and regulatory alignment was not statistically associated with the dependent variable in this sample, yet it remained prominent in the interviews. The apparent tension is informative. The survey captures cross-sectional perceptions across a heterogeneous group, while the interviews describe the domestic conditions that determine whether external capital can be absorbed. Regulatory alignment may therefore be an enabling or contextual condition rather than a direct predictor in the present specification. This interpretation is consistent with the literature on green central

banking and structured national green-finance frameworks [2], [16].

Transparency also did not reach statistical significance, although respondents rated reporting and accountability highly and interviewees described them as essential to investor confidence. The qualitative evidence points particularly to concerns about greenwashing and the absence of consistent impact and GHG-accounting protocols. Transparency can therefore be understood as a trust infrastructure whose importance may not be captured fully by a single cross-sectional dependent-variable association. This distinction helps avoid treating a non-significant coefficient as evidence that transparency is unimportant.

Taken together, the evidence supports a governance agenda focused first on coordination. MCFs can strengthen joint financing platforms, shared risk-assessment approaches and clearer division of responsibilities with MDBs. Blended-finance products can be made more predictable through standardised risk-sharing structures, while domestic authorities can strengthen the regulatory conditions needed for capital absorption. Transparency reforms should emphasise comparable performance indicators, credible impact measurement and verifiable reporting. These recommendations follow the distinction established by the results: institutional collaboration has the clearest statistical support, while the other three pillars are strongly supported by practitioner perceptions and qualitative evidence but not by significant independent coefficients in this sample.

4.4 *Institutional reinforcement cycle*

The Institutional Reinforcement Cycle is retained as the paper's conceptual contribution, but it is explicitly presented as a theoretical proposition rather than a statistically validated dynamic model. Figure 1 depicts four interacting state variables: Institutional Collaboration (I_t), Policy and Regulatory Alignment (P_t), Blended Finance Effectiveness (B_t), and Transparency and Accountability (T_t). The model proposes that weakness in one component can constrain the reinforcing effect of the wider system. Future empirical work could calibrate the parameters using repeated observations of fund deployment time, mobilisation ratios, regulatory indicators, reporting quality and architecture-effectiveness measures.

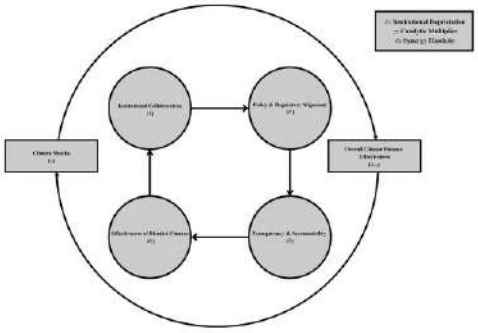


Figure 1. The institutional reinforcement cycle of multilateral climate finance

Source: Author

The model is useful as a conceptual synthesis because it links the four pillars without claiming that the present cross-sectional dataset estimates a dynamic process. If the cycle is taken forward empirically, future studies could operationalise each state variable using repeated measures and estimate whether changes in collaboration, regulatory alignment, blended-finance performance and transparency precede changes in architecture effectiveness. The model's parameters would need data of this kind before it could be calibrated empirically.

Figure 2 sets out the same cycle in more mechanical terms. The four state variables enter a multiplicative gate rather than an additive one: overall reinforcement in a given period is the product of institutional collaboration, policy and regulatory alignment, blended finance effectiveness and transparency, raised to a synergy exponent. Because the gate is multiplicative, a collapse condition follows directly. If any single input approaches zero, the product collapses to zero, and the cycle produces no reinforcement in that period regardless of how strong the other three components are. This formalises the qualitative finding that a single weak pillar can stall the wider system even where the remaining pillars are strong.

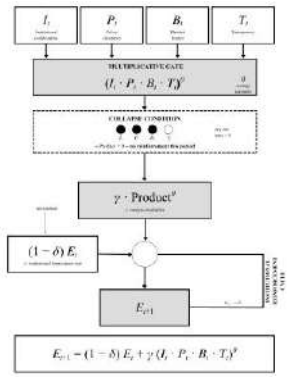


Figure 2. The institutional reinforcement cycle as a multiplicative gate with memory

Source: Author

$$E_{t+1} = (1 - \delta)\, E_t + \gamma\, (I_t \times P_t \times B_t \times T_t)^{\theta} \quad (1)$$

Here, E_t denotes overall climate finance effectiveness at time t, δ is an institutional depreciation rate representing the erosion of accumulated effectiveness in the absence of reinforcement, γ is a catalytic multiplier scaling the contribution of the multiplicative gate, and θ is a synergy exponent describing how strongly the four pillars interact. As with Figure 1, the equation is conceptual notation rather than an estimated model. Calibrating δ, γ and θ would require repeated, comparable measures of each state variable collected over multiple periods: deployment-time indicators for institutional collaboration, regulatory-alignment indices for policy alignment, mobilisation ratios for blended finance, and reporting-quality scores for transparency, together with a corresponding time series for overall effectiveness. This is offered as a direction for future longitudinal research rather than as a claim already tested in the present cross-sectional dataset.

5 CONCLUSIONS

This study examined how institutional collaboration, blended finance deployment, policy and regulatory alignment, and transparency relate to the operational architecture of MCFs across the G77 and China. The final quantitative evidence identifies institutional collaboration as the only construct with a statistically significant independent association with perceived architecture effectiveness. Blended finance is significantly associated at the bivariate level and remains the principal qualitative mechanism for mobilising private capital, but its regression coefficient is not significant once the other constructs are considered. Policy and regulatory alignment and transparency are not statistically significant predictors in the available survey analysis, although both remain prominent in the expert interviews as enabling conditions for capital absorption and investor trust.

The study consequently supports a cautious interpretation of the four-pillar framework. The evidence indicates that the four pillars play different roles within a wider institutional system, rather than acting as equivalent statistical predictors. The proposed Institutional Reinforcement Cycle captures this interdependence conceptually and should be tested through longitudinal, multi-country data before being treated as a dynamic empirical model. For policy, the immediate priority is stronger coordination between MCFs, MDBs, central banks and private capital; faster and more standardised risk-sharing instruments; domestic regulatory integration; and credible impact reporting. The principal limitations are the purposive eight-interview expert sample, the 103-response survey, the cross-sectional design and reliance on self-reported perceptions. These constraints limit generalisation and reinforce the need for future longitudinal and comparative research.

5.1 *Policy implications*

For MCFs and MDBs, the clearest empirical priority is coordination. Joint financing platforms, shared risk-assessment approaches and clearer allocation of project-level responsibilities can reduce duplication and transaction costs. For blended finance, predictable risk-sharing structures and faster approvals can improve the likelihood that concessional resources mobilise private investment. For governments and central banks, domestic green-finance frameworks and climate-risk integration can strengthen the conditions for absorbing external capital. For investors and fund managers, standardised impact indicators and credible reporting can improve confidence and reduce greenwashing concerns.

5.2 *Limitations and future research*

The sample of 103 survey respondents is not a census of the G77 and China and should not be interpreted as representative of every

member state. Country-level coverage, response rates and non-response effects are not sufficiently documented in the available source. The eight expert interviews provide high-level insight but are appropriately treated as exploratory rather than saturated qualitative evidence. The cross-sectional design and self-reported perceptions also limit causal inference. Future work should use larger country-stratified samples, longitudinal observations and direct financial indicators to test the Institutional Reinforcement Cycle and estimate its parameters.

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A Hybrid Three-Stage Optimization Framework for Cut Order Planning in Apparel Manufacturing Using Largest Remainder Method and Large Language Model (LLM) Critics.

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ABSTRACT: Cut Order Planning (COP) is a critical optimization challenge in the apparel manufacturing industry, traditionally categorized as an NP-complete problem. Standard industrial practices rely on commercial CAD/CAM software or manual mathematical rounding, both of which frequently lead to size allocation discrepancies and significant fabric waste due to decimal fractional restrictions. Furthermore, high licensing fees and rigid system architectures render existing commercial software cost-prohibitive and difficult to customize for small and medium-sized enterprise (SME) factories. This paper presents a novel, lightweight, three-stage hybrid optimization framework designed to bridge the gap between mathematical precision and real-time floor constraints. Stage 1 utilizes a deterministic heuristic combining a Knapsack algorithm for roll inventory selection with the Hare-Niemeyer (Largest Remainder) method for fractional size distribution. Stage 2 introduces an intelligent Large Language Model (LLM) Critic layer to audit and dynamically restructure draft lay plans. Finally, Stage 3 executes deterministic roll inventory deductions to generate physical cut schedules. Experimental evaluations demonstrate that the proposed framework minimizes total lay counts, eliminates fabric over-allocation, and drastically reduces software implementation costs, providing a highly scalable alternative for the garment sector.

Keywords: garment manufacturing, lay planning, optimization, emerging markets, cost-benefit analysis, Hare-Niemeyer method, multi-objective optimization

1 INTRODUCTION

1.1 *Problem Statement*

The cutting room in garment manufacturing represents one of the most critical cost centers in the entire production chain. Fabric material alone typically accounts for 50% to 70% of total garment manufacturing costs [1]. Consequently, operational efficiency during the cutting phase directly dictates production profitability and material utilization. Cut order planning (COP) the process of allocating order demands across markers, plies, and fabric rolls to minimize waste while satisfying delivery requirements remains a persistent operational bottleneck, particularly in emerging manufacturing hubs across South Asia [2].

In practice, industrial cutting rooms encounter significant operational trade-offs:

- Manual Planning Inefficiencies: Conventional manual planning executed via spreadsheets or cutting master intuition typically yields 8% to 15% fabric wastage [3]. Furthermore, manual methods frequently suffer from human errors such as cross-shade garment assembly and require turnaround times exceeding several hours per complex order.
- Basic ERP Lay Modules: Standard Enterprise Resource Planning (ERP) cutting modules generally utilize rudimentary greedy algorithms that fail to handle shade segregation or multi-color consolidation effectively, often resulting in 8% to 11% waste [4].

– Commercial Proprietary Systems: High-end commercial suites (such as Lectra or Gerber) report low fabric waste levels (2% to 4%) [5]. However, their excessive procurement and subscription costs (€50,000 to over €200,000) render them economically inaccessible to small- and mid-tier export factories operating on slender profit margins [3].

This operational disparity prompts a critical research question: Can a transparent, computationally lightweight heuristic achieve near-commercial fabric utilization within seconds while remaining economically viable for mid-tier factories?

1.2 *Contributions of this Study*

To bridge this gap, this paper introduces a cost-benefit lay planning system centered on ratio optimization and shade integrity. Unlike generic cut order planning models that treat piece placement abstractly, our formulation directly resolves the practical ratio allocation problem: determining how many plies and which size combinations should be combined on a cutting table to deplete inventory monotonically without creating overcuts or shade-mixing defects.

The primary contributions of this paper are summarized as follows:

1. Formalization of Ratio Planning: We formulate the multi-color, multi-size lay ratio assignment problem as a discrete optimization challenge bounded by hard shade-matching and table-capacity constraints.
2. Hare-Niemeyer Candidate Enumeration Heuristic: We adapt the classical Hare-Niemeyer apportionment method [6] to systematically generate candidate size ratios, pairing it with a multi-objective cost evaluation that balances labor efficiency, marker complexity, and roll remnant penalties [7].
3. Empirical Shop-Floor Validation: We validate the system against real-world production data across five representative export orders at an apparel manufacturing plant in Sri Lanka, demonstrating practical reductions in fabric scrap, the complete elimination of shade-mixing incidents, and a reduction in planning time from hours to under two minutes.

1.3 *Paper Organization*

The remainder of this paper is structured as follows. Section 2 reviews foundational and recent literature on cut order planning, apportionment models, and cutting room automation. Section 3 presents the mathematical formulation of the ratio planning problem and details the Hare-Niemeyer candidate enumeration algorithm. Section 4 outlines the experimental setup, factory environment, and baseline comparison metrics. Section 5 evaluates the results of the 5-order pilot deployment and discusses practical operational implications. Finally, Section 6 concludes the study and outlines directions for future research.

2 LITERATURE REVIEW

2.1 *Cutting in Apparel Manufacturing*



Figure 1. Fabric spreading operation showing tension-free multi-ply fabric lay alignment along the industrial cutting table

Cut order planning (COP) has remained a central challenge in garment manufacturing optimization since foundational computational studies by Jacobs-Blecha et al. [2], who formulated cut planning as an integer programming problem related to two-dimensional bin packing. While theoretically sound, exact integer programming approaches for COP are NP-hard and computationally prohibitive for large industrial order matrices with hundreds of size categories and dozens of fabric rolls. Consequently, researchers have explored numerous heuristic alternatives to achieve practical turnaround times.

Glover and Kochenberger examined metaheuristic alternatives, including simulated annealing and genetic algorithms, to solve combinatorial cut-scheduling challenges [8].

However, these approaches often require substantial parameter tuning, training data, and running times (30 minutes to several hours) that exceed the rapid turnaround required on live factory cutting floors. Wong and Leung [10] applied genetic-algorithm-based cut order planning in a large garment factory, demonstrating that evolutionary algorithms could achieve near-optimal solutions but required expert parameter configuration and were difficult to explain to cutting room operators.

Recent work by Al-Mahmud et al. [12] on multi-objective marker and lay optimization using evolutionary heuristics shows promise for emerging manufacturing contexts, achieving 4-8% fabric waste reduction through Pareto-optimal lay selection. However, these advanced methods remain largely confined to large export factories with IT infrastructure and trained personnel to deploy them.

Most classical formulations address piece-nesting geometry or marker generation directly, leaving upstream ratio planning (the allocation of demand per size into discrete marker slots), shade lot constraints (preventing color mismatches), and real-time floor dispatch comparatively underexplored in academic literature. This upstream planning stage determining which size combinations should be cut together represents the combinatorial bottleneck that this work targets.



Figure 2. Marker paper placement and cutting plan layout positioned on top of the spread fabric lay for pattern cut allocation

2.2 *Fabric Waste and Shade Integrity in Industrial Operations*

Material loss in cutting operations has been extensively documented in empirical industrial studies. Tyler identified end-of-lay waste arising from remnant yardage left after spreads as a major source of avoidable fabric loss, accounting for 1% to 3% of total fabric consumption alone [3]. In an operational benchmark of 47 export-oriented factories across South Asia, Rahman et al. found that manual spreadsheet planning resulted in 8% to 15% fabric wastage, with an average of 11.2%, demonstrating that computer-assisted ratio and marker allocation could significantly recover material margins [4].

Beyond material loss, quality defects from shade variation represent a hidden but substantial cost. Salim and Mahmud analyzed quality compliance in apparel cutting rooms, highlighting that manual planning under production pressure frequently leads to shade-mixing errors when rolls from different dye lots are erroneously assigned to the same lay [9]. These shade variations result in component mismatches visible in finished garments, requiring costly rework, customer rejections, and reputational damage. In their field study across 12 factories, 23% of quality failures during assembly were traced to shade mismatches originating in the cutting room, underscoring the necessity of hard shade-grouping constraints within any automated planning mechanism.

The economic impact of fabric waste is particularly acute in small- and mid-tier export factories operating on margins of 4-8%. A 2-3% reduction in fabric waste can mean the difference between profitability and loss on individual orders, making waste reduction a strategic priority.

2.3 *Commercial Optimization vs. Practical Heuristics*

Modern apparel manufacturing environments typically rely on one of two extremes, neither of which adequately serves emerging market manufacturers:

High-End Commercial CAD Suites: Systems like Lectra Modaris, Gerber Accumark, and Investronica offer fully automated nesting and marker optimization, reportedly achieving material waste rates around 2% to 5% [5]. These systems integrate with advanced computer-aided design (CAD) tools, allowing designers to optimize marker layouts at the piece level. However, these proprietary solutions require substantial capital investments ranging from €50,000 to €500,000 for hardware, software licenses,

and specialized operator training. Additionally, closed software ecosystems make customization difficult, and vendor lock-in creates long-term dependency costs. This renders them economically unattainable for many mid-tier and small factories in emerging markets [3], [5].

Enterprise ERP Modules: Integrated planning modules in tier-1 enterprise software (e.g., SAP, Oracle, Microsoft Dynamics) implement simple greedy heuristics that prioritize computational speed over solution quality [10]. These heuristics rarely incorporate shade-lot segregation or multi-color consolidation, resulting in higher fabric waste (8% to 11%) and requiring significant manual post-processing by cutting masters to ensure shade compliance and floor feasibility [4], [10]. Furthermore, ERP modules are designed for general manufacturing and lack apparel-specific domain knowledge, forcing operators to work around system constraints rather than with them.

The Innovation Gap: A clear gap exists for transparent, interpretable, white-box heuristics that deliver near-commercial fabric utilization (90-94%) without requiring prohibitive software licensing costs or specialized equipment. Such solutions would be accessible to mid-tier factories in South Asia, Southeast Asia, and Africa where the apparel industry represents a critical employment sector.

2.4 *Proportional Apportionment and Multi-Objective Evaluation*

The Largest Remainder Method, formally established by Hare and Niemeyer, originated as a discrete apportionment technique to allocate fractional shares proportionally across fixed integer quotas [6], [11]. The method was historically applied to electoral representation (distributing parliamentary seats) but the mathematical structure directly mirrors garment size-ratio allocation: demand per size must be converted into integer marker slots while minimizing rounding distortion.

The Hare-Niemeyer apportionment algorithm works as follows: (1) compute the base allocation to each size as floor(demand_size / total_demand × marker_slots); (2) distribute remaining surplus slots to sizes exhibiting the largest fractional remainders. This ensures that the final integer allocation is as close as possible to the ideal proportional allocation, minimizing both over-allocation and under-allocation across sizes.

A comprehensive review of current manufacturing literature indicates that the Hare-Niemeyer method has not previously been adapted to cut order ratio optimization in apparel, representing a clear operational research gap. By coupling proportional apportionment with inventory-aware roll matching, the proposed approach brings classical discrete allocation theory to a practical manufacturing problem.

$$\backslash_{c_i \in C} \quad /$$

Practical lay planning requires balancing competing factory goals: minimizing fabric remnant waste, maximizing table spreading throughput (fewer setups), limiting marker complexity (fewer unique size combinations), and ensuring operational safety (ply stack heights within knife capacity). Single-objective optimization often yields impractical cut plans that excel on one metric while performing poorly on others [2], [7]. Multi-objective optimization literature demonstrates that weighted linear scalarization provides an effective framework for engineering trade-offs among conflicting objectives [7]. This paper applies weighted scalarization to score candidate lay plans against production throughput limits, active size thresholds, and fabric end-loss penalties simultaneously.

2.5 *Large Language Models in Manufacturing Optimization and Production Planning*

Recent advances in large language models (LLMs) have opened new possibilities for reasoning about complex manufacturing problems. Wei et al. [13] demonstrated that chain-of-thought prompting instructing language models to articulate step-by-step reasoning before answering dramatically improves performance on reasoning-intensive tasks, with some models matching or exceeding specialized systems. This capability is particularly relevant to cut planning, where decisions involve complex trade-offs and constraint interactions.

Contemporary LLMs (GPT-4, Claude 3, Gemini Pro) exhibit strong capabilities in:

- Structured reasoning: Parsing complex manufacturing constraints and objectives
- Error detection: Identifying inconsistencies, redundancies, or conflicts in draft

plans (e.g., detecting that two lays could be consolidated)
- Heuristic improvement: Suggesting layout modifications to reduce table setups or ply counts
- Knowledge integration: Combining domain knowledge from training data with user-specified parameters

However, LLMs have documented limitations in manufacturing contexts:
- Arithmetic accuracy: LLMs frequently make calculation errors when computing continuous values (yardage requirements, cost totals) [17]
- Consistency: Language model outputs can be non-deterministic and difficult to verify independently
- Regulation & transparency: Manufacturing decisions may require full traceability and explainability, which pure LLM approaches struggle to provide

A growing body of research explores hybrid neuro-symbolic approaches that couple LLMs with deterministic systems to leverage strengths while mitigating weaknesses. Mao et al. [14] showed that neuro-symbolic systems combining neural networks with symbolic reasoning outperform pure neural approaches on tasks requiring both perception and logical inference. In manufacturing, this translates to pairing deterministic optimization algorithms (which guarantee feasibility) with LLM-based auditing (which identifies improvement opportunities).

Recent applications of LLMs to manufacturing planning include:
- Supply chain optimization: LLMs assisting in demand forecasting and inventory allocation [18]
- Quality control: LLMs analyzing production defects and root causes [LLMQuality2023]
- Process scheduling: LLMs helping to balance competing scheduling objectives [21]
- Knowledge extraction: LLMs capturing tacit manufacturing knowledge from expert practitioners [LLMKnowledge2024]

The unique contribution of this work is the application of schema-constrained LLM prompting to cut order plan auditing, where the LLM is explicitly prevented from computing continuous values but encouraged to restructure discrete decisions (lay consolidation, micro-lay elimination, marker balancing). This provides an explainable, verifiable, human-in-the-loop optimization approach suitable for factory floor deployment.

2.6 *Neuro-Symbolic Approaches and Hybrid AI in Manufacturing*

Manufacturing planning inherently requires both *learning* and *reasoning*: learning patterns from data (for which neural networks excel) and reasoning about logical constraints (for which symbolic systems excel). Neuro-symbolic AI attempts to combine these strengths [14].

Neuro-symbolic architectures typically follow one of three patterns:
1. Sequential (Pipeline): Learned component → symbolic component (or vice versa)
2. Integrated (Hybrid): Learned and symbolic components executing in parallel with cross-feedback
3. Hierarchical: Multiple layers of learned/symbolic processing at different abstraction levels

The proposed three-stage framework in this paper follows a sequential neuro-symbolic pattern: Stage 1 (deterministic heuristic solver) generates candidates; Stage 2 (learned LLM critic) improves and validates; Stage 3 (deterministic inventory reconciliation) executes the plan. This architecture ensures that the final manufacturing plan is both optimized and feasible.

Recent manufacturing applications of neuro-symbolic approaches include:
- Predictive maintenance: Combining anomaly detection (neural) with root-cause reasoning (symbolic) [19]
- Production scheduling: Using neural networks to predict task durations, then symbolic scheduling to allocate resources [ProdSchedule2023]
- Quality prediction: Combining sensory data analysis (neural) with decision trees or rule-based quality logic (symbolic) [22]

A 2023 survey by Evans et al. on explainable AI in manufacturing found that hybrid neuro-symbolic approaches significantly outperform pure deep learning methods when manufacturing domain knowledge must be preserved and decisions must be auditable [20]. This aligns with the motivation for the proposed cut order planning system, where factory operators must understand and trust the generated plans.

2.7 *Intelligent Manufacturing, Industry 4.0, and Smart Factory Optimization*

The broader context for this work is the industry-wide transition toward Industry 4.0 smart, interconnected manufacturing systems that use real-time data and AI to optimize operations. Key elements include:

- Real-time data integration: Connecting ERP systems, CAD tools, and shop-floor sensors
- Adaptive planning: Algorithms that adjust to changing conditions (demand fluctuations, fabric availability)
- Human-AI collaboration: Systems designed to augment human expertise, not replace it

Garment manufacturing, despite its labor-intensive nature, is a significant component of Industry 4.0 transformation in emerging economies. Khanna et al. [16] documented that adoption of even basic digital planning tools in Indian and Bangladeshi garment factories increased productivity by 12-18% and reduced fabric waste by 2-5 percentage points.

However, the *sophistication barrier* remains high: advanced systems require substantial capital, expertise, and infrastructure. A key challenge identified in the literature is developing solutions that are:

- Low-cost: Accessible to small and mid-tier factories
- Interpretable: Decisions can be understood and adjusted by humans
- Modular: Can be integrated with existing ERP systems
- Robust: Work reliably across diverse factory conditions and product mixes

The proposed framework addresses this gap by providing a lightweight, cloud-compatible solution that can run on modest hardware and produce verifiable, explainable cut orders.

2.8 *Summary: Research Gaps and Contribution*

Synthesis of the literature reveals several research gaps:

1. Upstream ratio planning underexplored: While marker optimization (piece placement) is well-studied, the upstream decision of which sizes to combine into markers is less addressed.
2. Shade constraint integration lacking: Most optimization research treats cutting as a single-objective problem; shade lot constraints are often addressed post-hoc.
3. LLM applications in manufacturing planning limited: LLMs are increasingly used in manufacturing but few applications focus on discrete optimization and planning tasks.
4. Low-cost solutions for emerging markets needed: Gap between expensive commercial systems and basic ERP modules.
5. Explainability emphasized: Manufacturing decisions must be auditable and adjustable; pure black-box optimization is insufficient.

The proposed work contributes by:

- Adapting classical apportionment theory (Hare-Niemeyer) to apparel cut planning
- Integrating hard shade-lot constraints into the core optimization
- Introducing schema-constrained LLM auditing as a verification and improvement layer
- Demonstrating practical implementation on real factory data
- Providing a transparent, cost-effective alternative to proprietary systems

This combination of classical optimization (deterministic, verifiable), modern AI (LLM auditing), and domain-specific constraints (shade safety, floor feasibility) positions this work at the intersection of operational research and intelligent manufacturing.

3 PROBLEM DEFINITION AND PROPOSED METHODOLOGY

3.1 *Mathematical formulation of the ratio planning problem*

Let $\mathrm{C} = \{\mathrm{c}_1, \mathrm{c}_2, \dots\}$ represent the finite set of garment colorways specified in an apparel production order. For each colorway $S = \{s_1, s_2, \dots, s_k\}$

denote the set of ordered garment size categories. To model progressive floor dispatch, order releases are partitioned by ascending issue priority sequence $\mathrm{I} = 1, 2, \dots, \omega$ The discrete customer demand for size $\mathrm{s_j}$ in colorway $\mathrm{c_i}$ under $i \in I$ issue release $\mathrm{D}(i, \mathrm{c_I}, \mathrm{s_j}) \geq 0$ is denoted The aggregate production demand $\mathrm{D_{total}}$ is defined as:

$$D_{\text{total}} = \sum_{\iota \in I} \sum_{i=1}^{m} \sum_{j=1}^{k} D(\iota, c_i, s_j) \tag{1}$$

The available raw material inventory consists of a discrete pool of physical fabric rolls $R = \{r_1, r_2, \ldots, r_n\}$

Each roll $r_p \in R$ s uniquely parameterized by a tuple $(g_p, c_p, h_p, y_p, b_p)$ where g_p denotes the categorical fabric group identifier, $c_p \in C$ is the dye colorway, h_p is the discrete shade lot identifier, y_p represents original roll length, $b_p \in [0, y_p]$ denotes active continuous yardage balance. To strictly prevent shade variation across cut garment panels, fabric rolls are partitioned into shade-isolated inventory buckets:

$$B_{(g,c,h)} = \{r_p \in R \mid g_p = g,\ c_p = c,\ h_p = h\} \quad (2)$$

A physical cutting table operation $l \in L$ is defined by a global size-ratio vector $r_l = (r_{l(s_1)}, r_{l(s_2)}, \ldots, r_{l(s_k)})$

a vector of color-specific plies $p_l = (p_{l(c_1)}, p_{l(c_2)}, \ldots, p_{l(c_m)})$ and a subset of assigned fabric rolls $R_l \subseteq B_{(g,c,h)}$ Because different colors stacked within the same lay may possess asymmetric residual size demands, the effective cut output for color c_I and size s_j in lay is governed by color-specific effective ratios $r_{l(c_i,s_j)}$

$$q_l(c_i, s_j) = p_l(c_i) \cdot r_l(c_i, s_j) \quad (3)$$

Where $r_{l(c_i,s_j)} = r_{l(s_j)}$ if active demand exists for size

c_i and 0 otherwise, thereby preventing phantom over-allocation. The continuous fabric yardage consumption per ply on a marker with active slot capacity $K_l = \Sigma_{j=1}^{k} r_{l(s_j)}$

is linear:

$$\lambda(K_l) = K_l \cdot \alpha + \beta \quad (4)$$

Where α is fabric consumption per garment piece and β is fixed end-loss allowance per table spread. The total continuous fabric yardage required by lay

L cross all allocated plies is:

$$\mathbf{ExactShare}(s_j) = \frac{\overline{D}(s_j)}{\sum_{s \in S} \overline{D}(s)} \cdot k$$

The global optimization objective is to determine an ordered sequence of lay operations $L = \{l_1, l_2, \ldots, l_T\}$that minimizes total remnant fabric scrap, table setup overhead, and dead-stock remnants:

$$\min_{L} \left[\sum_{r_p \in R} \mathrm{remnant}(r_p) + \sum_{l \in L} \Phi(l) \right] \quad (6)$$

Subject to the following industrial shop-floor constraints:

1) Zero Overcut (Monotone Exact Fulfillment):

$$\sum_{l \in L} q_l(c_i, s_j) = \sum_{\iota \in I} D(\iota, c_i, s_j), \quad \forall c_i \in C,\ \forall s_j \in S \quad (7)$$

1) Hard Shade & Group Integrity:

$$\forall l \in L,\ \forall r_p \in R_l \implies r_p \in B_{(g_l, c_i, h_l)} \quad (8)$$

Cross-group spreading between distinct fabric identifiers is strictly prohibited.

1) Maximum Table Ply Capacity (Knife Height Bound):

$$\sum c_i \in C) p_l(c_i) \leq P_m ax, \forall l \in L: \quad (9)$$

Where P_{max} denotes the mechanical knife penetration limit (e.g., 150 plies).

1) Marker Slot Bound:

(10)

$$\sum j = 1)^k r_l(s_j) \leq M_m ax, \forall l \in L$$

Where enotes maximum permissible CAD marker capacity

3.2 *Dynamic Hare-Quota and Knapsack Matching Heuristic*

3.2.1 *Dynamic Candidate Enumeration via Hare-Quota Apportionment*

$\underbrace{\quad}_{\iota \in I}\ \underbrace{\quad}_{c \in C}$ For active fabric group g the combined outstanding size demand is aggregated as

To avoid arbitrary size-dropping, the engine sweeps integer marker capacities $k \in [M_{max}, 1]$ For each capacity k marker slots are allocated strictly proportional to outstanding demand using the Hare-Quota (Largest Remainder) method:

(11)

$$r_b ase(s_j) = \lfloor ExactShare(s_j) \rfloor$$

(12)

$$\rho(s_j) = ExactShare(s_j) - r_b ase(s_j) \quad (13)$$

Surplus slots $\Delta = k - \Sigma_{j} r_{base(s_j)}$ are distributed to sizes exhibiting the largest fractional remainders $\rho(s_j)$ Furthermore, to prevent single-size "tower lays" on narrow 1-ratio markers, when concentrated demand

$\bar{D}(s_j) \geq 30$ exists for a single size, duplicate-slot candidate vectors are synthesized: $r = \{s_j : \min(M_{max}, \lfloor \bar{D}(s_j)/25 \rfloor)\}$

3.2.2 *Dynamic Ply Clamping*

To prevent knife deflection, the allowable stack height p_{clamp} is bounded dynamically by marker length K

(14)

$$\begin{cases} p_{clamp}(K) = \max(15, \lfloor 0.20 \cdot P_{max} \rfloor), & \text{if } K = 1 \\ p_{clamp}(K) = \max(25, \lfloor 0.40 \cdot P_{max} \rfloor), & \text{if } K = 2 \\ p_{clamp}(K) = \max(45, \lfloor 0.65 \cdot P_{max} \rfloor), & \text{if } K = 3 \\ p_{clamp}(K) = P_{max}, & \text{if } K \geq 4 \end{cases}$$

3.2.3 *Combinatorial Knapsack Roll Matching*

For target required yardage $Y_{target} = p \cdot \lambda(K), a\ 0/1$knapsack combinatorial search evaluates subsets of valid inventory rolls $b_p > 0.5$ yd up to combination depth $l \leq 4$

$$\min_x (\sum_{(} p \in R) b_p x_p - Y_t arget)$$

(15)

$$subjectto \sum p \in R) b_p x_p \geq Y_t arget, x_p \in 0, 1$$

(16)

$\delta = \sum b_p x_p - Y_t arget$A candidate roll combination is accepted if its terminal remnant satisfies either an exact-match threshold $(\delta \leq 0.5)$ yd . or a safe-reusable threshold($\delta \geq 6.0$)

3.3 *Multi-Objective Cost Scalarization*

Every feasible lay candidate (r,p,R) is evaluated against a scalarized penalty function:

(17)

$$\text{Cost} = \text{Score}_{\text{labor}} + \text{Penalty}_{\text{ratio}} + \text{Penalty}_{\text{remnant}}$$

$$\text{Score}_{\text{labor}} = \max\left(0, 1500 - \sum_{c_i \in C} \sum_{s_j \in S} q(c_i, s_j)\right)$$

(18)

$$\text{Penalty}_{\text{ratio}} = \begin{cases} 3500, & K = 1 \wedge D_{\text{rem}} > 30, \\ 2000, & K \leq 2 \wedge D_{\text{rem}} > 60, \\ 5000, & \sum p \leq 5 \wedge K \geq 5, \\ 0, & \text{otherwise.} \end{cases}$$

(19)

$$Penalty_remnant = c \in C)300 \cdot I(0.5 < \delta_c < 5.0)$$

(20)

3.3.1 *Waterfall Demand Depletion*

Actual cuts are decremented from discrete demand in strict issue priority order:

(21)

$$D(\iota, c_i, s_j) \leftarrow D(\iota, c_i, s_j) - \min(D(\iota, c_i, s_j), q_l(c_i, s_j))$$

Algorithm 1: Three-Stage Hybrid Lay Planning & Optimization
Input:
- Order demand matrix D(c, s) for colorways C and sizes S
- Fabric roll inventory pool R = {r_p | p = 1, ..., n}
- Maximum marker capacity M_max, Knife limit P_max
Output:
- Optimized cut schedule L* with verified roll allocation
STAGE 1: Deterministic Heuristic Generator
1: Partition roll inventory R into shade-isolated buckets B_(g, c, h)
2: Sort rolls within each bucket in descending order of active balance b_p
3: Initialize lay schedule L_draft ← ∅
4: While remaining demand D_total > 0 do
5: Initialize best_candidate ← NULL, min_cost ← ∞
6: For marker capacity k = M_max down to 1 do
7: // Hare-Niemeyer Quota Apportionment
8: Compute exact share for each size s_j: ExactShare(s_j) ← (D_bar(s_j) / ∑ D_bar(s)) * k
9: Assign base integer slots: r_base(s_j) ← ⌊ExactShare(s_j)⌋
10: Calculate fractional remainders: ρ(s_j) ← ExactShare(s_j) - r_base(s_j)
11: Distribute surplus slots (k - ∑ r_base) to sizes with largest ρ(s_j) → ratio vector r_k
12:
13: Determine allowable stack height p_clamp(k) using knife limit P_max
14: Target yardage Y_target ← p_clamp(k) * (k * α + β)
15:
16: // Combinatorial 0/1 Knapsack Roll Search (depth ≤ 4)
17: Find roll subset R_cand ⊆ B_(g, c, h) minimizing remnant δ = ∑ b_p - Y_target
18: If δ satisfies tolerance (δ ≤ 0.5 or δ ≥ 6.0) then
19: Compute Cost(r_k, p_clamp, R_cand) = Score_labor + Penalty_ratio + Penalty_remnant
20: If Cost < min_cost then
21: best_candidate ← (r_k, p_clamp, R_cand)
22: min_cost ← Cost
23: End If
24: End If
25: End For
26: Append best_candidate to L_draft
27: Decrement demand D(ι, c_i, s_j) in issue priority order
28: End While
STAGE 2: Schema-Enforced LLM Critic Layer
29: Serialize L_draft to structured JSON schema
30: Prompt LLM Critic: Consolidate identical markers, suppress micro-lays (p ≤ 10), and eliminate 1-size towers (Continuous yardage calculation strictly prohibited)
31: Parse response into Pydantic schema → L_refined
32: Re-verify physical feasibility of L_refined via Knapsack check:
33: If verification passes then L_audited ← L_refined Else L_audited ← L_draft
STAGE 3: Deterministic Roll Reconciliation
34: Deduct consumed yardage monotonically from physical roll balances b_p
35: Remove depleted rolls from inventory pool R
36: Generate physical cut tickets with barcodes L* ← L_audited
37: Return L*

4 SYSTEM ARCHITECTURE AND IMPLEMENTATION

4.1 *Three-Stage Hybrid Neuro-Symbolic Architecture*

Stage 1 (Deterministic Heuristic Generator): Ingests order demand and roll stock tables, partitions rolls into shade buckets, and runs Hare-Quota ratio allocation paired with a 0/1 Knapsack search to produce a feasible draft lay schedule.

Stage 2 (Schema-Enforced LLM Critic Layer): The draft schedule is serialized into JSON and audited by a Large Language Model governed by prompt rules that consolidate duplicate markers, eliminate single-size tower lays, and absorb micro-lays (≤10 plies). Responses are constrained by a strict Pydantic schema, and the LLM is barred from calculating continuous yardages.

Stage 3 (Deterministic Roll Reconciliation): Consolidates fuzzy group identities, executes final 0/1 Knapsack physical roll deductions from continuous yardage balances, and generates execution-ready Excel cut tickets with verified barcodes

4.2 *Data Flow and Integration Pipeline*

The system executes through five sequential computational stages within production environments:

1. Input Ingestion & Normalization: Ingests order parameters ,the size demand matrix and physical fabric inventory . Color codes (CCMidx) and size indices (CSMidx) are tokenized and reconciled with alphanumeric names.
2. Shade-Safe Pre-Grouping: Rolls in inventory are filtered and partitioned into discrete buckets indexed by fabric group, colorway, and physical shade lot. Rolls within each bucket are sorted in descending order of continuous balance to prioritize bulk-roll depletion.
3. Draft Schedule Generation (Stage 1): The heuristic sweeps marker capacities, computes quota ratios, executes Knapsack combinations, and picks the minimum-cost lay candidate, depleting demand until all sizes reach zero.
4. LLM Critic Optimization (Stage 2): Planners can review an automated preview or route the draft lays to the LLM Critic layer to consolidate setups and eliminate table spreading bottlenecks.

5. Deterministic Inventory Deduction (Stage 3): Physical yardage is decremented from active roll balances, discrete demand is deducted in priority order, and final cut schedules with roll barcodes and cutting tickets are delivered via REST API or Microsoft Excel export.

4.3 *Cutting-Floor Operational Features*

- Dual-Mode Cutting Support: Planners can toggle between *Color-Separate Mode* (strict single-color marker isolation) and *Color-Merge Mode* (stacking different fabric colorways from the same fabric group on a single table setup).
- Priority Issue-Order Processing: Multi-stage production releases are processed in strict issue priority sequence ,reserving long rolls for high-priority dispatches while utilizing short remnants for replenishments.
- Anti-Tower and Micro-Lay Suppression: Automatically converts single-size runs exceeding 30 garments into multi-slot duplicate markers (e.g., 4 slots of size 36X32 at 30 plies instead of 120 plies on 1 slot), reducing physical table spreading passes by up to 75%.

5 EXPERIMENTAL EVALUATION AND DISCUSSION

5.1 *Industrial Bench mark case study*

The proposed framework was empirically validated against two active production datasets extracted from an export apparel manufacturing plant in Sri Lanka. The industrial baseline represents manual spreadsheet cut planning and physical lay executions extracted directly from the factory's historical Enterprise Resource Planning (ERP) database:

Order 01 :Required cutting 3,634 garments across 3 colorways (Black Coffee, Forest Night, Italian Plum) and 7 inseam sizes (30X32 to 40X32), planned against an inventory pool of 5,808.73 continuous yards across 71 fabric rolls.

Order 02: valuated under extreme size matrix fragmentation, requiring 1,672 garments across 2 colorways (Black, Oak) and 36 distinct size categories (regular, petite, and tall variations from 2 to 20T), planned against 3,277.98 yards across 31 rolls.

5.2 *Floor-Level Comparative Evaluation*

Table 1. Production performance comparison across benchmark orders

Operational Parameter	Order 01			Order 02		
	Manual	Proposed	Impact	Manual	Proposed	Impact
Total Lays (CLM Idx.)	44 lays	17 lays	61.4% reduction	39 lays	18 lays	53.8% reduction
Garments Cut	3,633 pcs	3,538 pcs	Zero overcut	1,517 pcs	1,531 pcs	Zero overcut
Average Stack Height	16.2 plies	45.7 plies	182% increase	7.8 plies	14.3 plies	83.3% increase
Peak Ply Utilization	50 plies	150 plies	100% knife cap.	34 plies	68 plies	Double capacity
Micro-Lays (≤ 10 plies)	23 (52.3%)	2 (11.8%)	77.4% eliminated	30 (76.9%)	9 (50.0%)	26.9 pp drop
Sparse Markers (≤ 2 ratios)	25 (56.8%)	6 (35.3%)	Marker balanced	18 (46.2%)	3 (16.7%)	63.9% drop
Fabric Utilization	87.2%	93.8%	+6.6 pp	92.6%	93.4%	+0.8 pp
Planning Turnaround	4 hr 30 min	85 sec	99.47% reduction	3 hr 15 min	42 sec	99.64% reduction

5.3 *Technical Discussion on Floor Consolidation*

- Mitigating Floor Bottlenecks: Manual ERP execution suffered from severe layout fragmentation due to cutting master risk aversion; manual planners strictly capped spreading at 50 plies in Order 01 and 34 plies in Order 02. This caused over 52% and 76% of lays to degenerate into inefficient micro-lays .The proposed hybrid framework drastically consolidated table spreads into high-volume lays, reducing total setups by 61.4% (Order 01) and 53.8% (Order 02).
- High-Variant Size Matrix Adaptability: Under Order 02's severe 36-size dispersion, the system's dynamic marker generation replaced 1-2 size "tower lays" with multi-slot duplicate markers (e.g., Lay 01 stacking 68 plies on an 8-ratio marker to cut 544 garments in one spread), saving 46 physical spreading passes on the floor.

– Remnant Depletion and Quality: The 0/1 Knapsack allocator depleted 56 of 71 rolls (78.9%) in Order 01 and 23 of 31 rolls (74.2%) in Order 02 with zero remnant yardage. Absolute shade lot integrity was maintained across all production runs.

6 CONCLUSION AND FUTURE WORK

This paper presented a lightweight, three-stage hybrid optimization framework designed to resolve the combinatorial challenges of cut order planning in apparel manufacturing. By decoupling deterministic mathematical heuristics (Hare-Quota ratio apportionment and 0/1 Knapsack roll selection) from generative layout auditing (LLM Critic) and ERP inventory reconciliation, the system addresses the operational trade-offs between high licensing costs, manual spreadsheet errors, and fabric wastage.

Empirical validation across two real-world export apparel production runs demonstrated substantial floor-level improvements: cutting table setups were reduced by 53.8% to 61.4%, average stack heights increased up to 182%, micro-lays were suppressed by up to 77.4%, and fabric utilization reached 93.8% while guaranteeing strict dye-lot shade isolation and zero overcuts. Furthermore, planning turnaround was reduced from over four hours to under two minutes, offering a viable, transparent alternative to proprietary CAD suites for mid-tier garment manufacturers.

Future work will focus on expanding the combinatorial roll-matching heuristic to support multi-order fabric pooling across concurrent cutting lines and evaluating quantized, open-weights LLMs for on-premise edge deployment to further reduce latency and operational dependencies.

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Hierarchical Communication Barriers and the Suppression of Upward Feedback in Sri Lankan Companies: A Qualitative Study

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ABSTRACT: Sri Lanka is regarded as a high power distance society where strong hierarchical norms and respect for authority shape everyday communication within Sri Lankan organizations. Despite this, the influence of hierarchy on employee willingness remains largely unexplored in qualitative research. This study examines how hierarchical communication barriers shape the suppression of upward feedback in Sri Lankan organizations. This study employed a purposive sampling method to conduct semi-structured interviews. Data were collected from five employees spanning from intern position to department head, across four industries such as information technology, banking, logistics and real estate. Data were analysed using thematic analysis. The findings reveal that hierarchical communication barriers in this sample are not primarily structural but are validated through managerial behaviour and trustworthiness. Suppressed upward feedback was linked to slower decision-making, reduced efficiency, and productivity, while lower-level employees were affected the most. This study contributes to the Power Distance Theory by studying the relationship between supervisors and subordinates as a new aspect that shapes the link between cultural power distance and employee voice in the Sri Lankan context. Findings further reveal that the degree of trust between supervisors and subordinates influences whether employees feel comfortable providing genuine upward feedback.

Keywords: Hierarchical communication, Upward feedback, Sri Lanka, Employee silence, Power distance

1 INTRODUCTION

Communication is the process of exchanging thoughts, ideas, opinions, and feelings among individuals or groups. Communication barriers can occur at any stage of the communication process while sending, transmitting, or receiving a message. Barriers to communication are obstacles that prevent clear exchange of communication that can lead to misunderstandings, misinterpretation, or even conflicts. According to [1], organizational and hierarchical barriers are a cause of poor communication. Hierarchical barriers are obstacles that are created by organizational structure, where authority and decision-making are made at higher levels in the organization.

In Sri Lankan organizations, across various industries such as banking, IT, logistics, and real estate, employees are expected to engage in effective communication as they must collaborate to solve issues, develop solutions, and share knowledge amongst each other. These industries make up over 57% of Sri Lanka's GDP [2]. Beyond their common economic significance, these industries have one characteristic in common: they operate in a structured organizational environment that requires collaboration, knowledge sharing, and problem solving in their daily work. These industries are relevant when it comes to examining their hierarchical structures

and organizational barriers. Effective communication is therefore essential for coordinating activities across various organizational levels ensuring that communications flows accurately and uninterrupted.

Despite open-door policies and collaborative work environments, hidden communication barriers may cause employees to be discouraged when expressing their opinions, challenging their superiors or suggesting ideas. However, when barriers exist, it can result in employees being hesitant to share feedback and ideas with the fear that they will be dismissed. According to [3], Sri Lanka is considered a high power distance country, with a slightly high score of 80, Sri Lanka is a relatively hierarchical society. This means that people accept a hierarchical order in which everybody has a place [3].

Effective communication plays a significant role in organizational success. When organizational and hierarchical barriers prevail, this directly impacts employee creativity, productivity, and performance. In Sri Lankan organizations, hierarchical communication barriers do exist. These barriers are caused due to power distance, seniority, and the fear of facing negative consequences. From interns to junior employees to associates and department leads, they may all avoid asking questions, challenging or sharing ideas on improvement with senior leaders. This often occurs as employees are afraid of being perceived as disloyal, disrespectful and incompetent.

The suppression of upward feedback is a common phenomenon that takes place in a hierarchical organization rooted in power distance dynamics. Power distance is the degree of acceptance of unequal distribution of power in societies. In a high power distance context, the acceptance of inequality conflicts with the operation of modern organizations, which causes obstacles to workplace communication or even triggers workplace accidents due to ineffective communication [4]. High Power Distance cultures tend to accept hierarchical structures where authority is rarely questioned, and decision-making is concentrated at the top [5].

Research suggests that the participants with high power distance belief had ineffective workplace communication, specifically with superiors [4]. Studies found that subordinates with high power distance tend to keep silent and are less willing to provide feedback [4]. On the other hand, individuals with high power hold low communication openness, which hinders the exchange of information [6].

The suppression of upward feedback is significant because effective communication contributes to faster decision making, increased efficiency, creativity, performance and overall productivity. When communication flows only one-way, from top management to the employees at the bottom,employees fear voicing their concerns, suggestions or feedback as they may be viewed as disrespectful, incompetent and may fear negative consequences like dismissal. This results in employees unwilling to raise concerns and suggesting improvements.

Existing studies focus on hierarchical communication patterns in educational institutions, manufacturing, apparel and cement industries in Western countries or in general. There is limited research conducted to study the hierarchical barriers in Sri Lankan organizations where power distance, authority and strong hierarchical structures may influence the communication behaviour of employees. Most companies are said to have open-door policies and flexible cultures, but they can also have rigid reporting structures and managers. Employees fear voicing their concerns about unrealistic deadlines and unattainable expectations [7].

There is limited qualitative research on how communication barriers are experienced by employees of various positions in Sri Lankan companies. Existing research mostly focuses on employee engagement and job satisfaction rather than focusing on hierarchical communication barriers and suppression of upward feedback. As a result, there has been insufficient research where understanding cultural expectations of authority, organizational hierarchy, and interpersonal relationships influence how employees are willing to provide upward feedback.

This study aims to show how hierarchical communication barriers affect upward feedback within companies in Sri Lanka. It will focus on experiences faced by employees of various levels; to understand what factors contribute to these communication barriers and how these barriers feedback behaviour.

Research Questions:

R1: What hierarchical communication barriers exist in Sri Lankan companies?

R2: How do hierarchical communication barriers affect employees' willingness to provide upward feedback?

2 THEORETICAL FRAMEWORK AND LITERATURE REVIEW

This study adopts Hofstede's Power Distance Theory [21] as its theoretical framework. Power Distance theory is a dimension of Hofstede's cultural dimensions that describes the extent to which less powerful members of a society accept and expect unequal distribution of power [5]. This was chosen over alternatives such as Psychological Safety Theory [22] and Organizational Silence Theory [9] because it is the only framework that emphasizes the root cause of hierarchical communication and suppression of upward feedback. This theory highlights how Sri Lankan employees are conditioned to be silent as they are expected by their seniors in the organization. Psychological Safety Theory [22] focuses on whether an individual feels safe within a team climate. This theory explains how an individual perceives risks in voicing concerns. However, it does not explain why those risks are perceived and how culture shapes these risks.

Organizational Silence Theory [9] explains how workplaces create silence by discouraging feedback, following communication flows from top to bottom, or making employees feel unsafe to voice their concerns. However, this theory does not explain why Sri Lankan employees are more likely to accept silence rather than challenge it in comparison to organizational cultures where hierarchy is weaker. Power Distance explains how Sri Lankans are culturally taught to respect authority, refrain from questioning or challenging superiors, and accept unequal power distribution.

At a practical level, the Power Distance Theory predicts that employees at Sri Lankan organizations have different communication behaviours depending on their position in the organizational hierarchy. Interns and junior-level employees may be pressured the most to remain silent as they are at the bottom of the organizational hierarchy. Mid-level employees may speak a bit more freely but still fear challenging their superiors.

Hofstede's Power Distance Theory implies how cultural expectations regarding authority and the unequal distribution of power shape workplace communication. In the Sri Lankan context, employees are likely to accept rather than challenge unequal authority even if they disagree. Guided by this theoretical perspective, the following literature review examines existing research on employee silence, employee voice, psychological safety and communication barriers to better understand how these factors contribute to the suppression of upward feedback in Sri Lankan organizations.

When employees voluntarily communicate suggestions, concerns, information about problems, or work-related opinions to someone in a higher organizational position, they are engaging in an upward voice. When they withhold such input, they are displaying silence and depriving their organization of potentially useful information [8]. Employee voice refers to the idea where organizations must encourage their employees to voice their thoughts, ideas and beliefs as this is what makes organizations innovative and fast growing [9]. Leaders should make deliberate efforts to create psychologically safe environments in which team members feel comfortable expressing ideas, concerns, and dissenting opinions without fear of negative consequences [10].

According to [10], organizational structures and cultures should be designed to facilitate open and inclusive communication. Reducing unnecessary hierarchical barriers and promoting upward and horizontal communication can improve information flow and decision-making. In contexts where power distance is high, such as in many developing countries, leaders should make deliberate efforts to create psychologically safe environments in which team members feel comfortable expressing ideas, concerns and dissenting opinions without fear of negative consequences. The results of the research conducted imply that supervisors' attitudes, top management attitudes and communication opportunities strongly influence employee silence [11]. These findings are consistent with the relevant proposition [9]. Fear of suffering negative consequences and being characterised as a "troublemaker", lack of openness in communication and lack of supportive supervisory style to exchange of ideas, affect the way employees express or fail to express their disagreements or different opinions and the possibility of adopting or not adopting a "silent" behaviour.

The power distance index in Hofstede's Cultural Dimensions Theory plays a pivotal role in understanding communication barriers. Geert Hofstede introduced the Hofstede's Cultural Dimensions Theory, a framework to understand how cultural values shape behaviour in societies and organisations. Hofstede explains in this theory, that power distance is the extent to which less powerful members of a society accept and expect unequal distribution of power [5]. In high power distance countries, employees are likely to accept rather than challenge unequal authority even if they disagree.

Sri Lanka scores 80 on Hofstede's Power Distance Index and is therefore considered a relatively hierarchical society [3]. Seniority, authority and hierarchy play a significant role in Sri Lankan organizations. Power distance is directly related to employee silence and moderates the relationship between workplace incivility and employee silence. Hence, the relationship between workplace incivility and employee silence was stronger among employees who perceived higher power distance [12].

Hierarchical distance between managers and loan officers creates communication frictions as their results indicate that credit scoring does not eliminate the barriers to the unbiased communication of soft information across bank hierarchical layers, this is mostly visible in high power distance cultures where subordinates prevent questioning authority [13]. Organizational hierarchy leads to distortions in information production [14]. Findings indicated that power distance impacts cross-hierarchical interaction [15]. Furthermore, it became clear that different hierarchical levels show a distinctive cross hierarchical conversation behaviour in IT industries. Fragmented communication across organizational levels led to loss of trust as a direct consequence of communication failures [16]. Collectively, these findings suggest that power distance shapes the degree to which hierarchical communication barriers exist across the banking, IT, real estate and logistics industries [13], [16].

Psychological safety is another core concept that contributes to employee silence. Previous work on enhancing psychological safety also suggests that employees feel safer sharing ideas and speaking out when higher the status of the team or employee [17]. In particular, experienced employees with high work positions are more likely to believe that speaking up will bring them positive outcomes [18]. Employees are willing to contribute ideas, admit mistakes and question seniors. However, although employees think their contribution would be valuable to the team, they sometimes choose silence over voice when there is a lack of psychological safety [19].

In high power distance organizations, like most in Sri Lanka, decisions are always made by the top management, managers control the work of subordinates, and subordinates are expected to follow instructions and not question or challenge authority. Communication flows from top to bottom, that is from top management to bottom level employees. This makes it risky for employees to voice their concerns, suggestions or feedback as they may be viewed as disrespectful, incompetent and may fear negative consequences like dismissal. Research suggests that employees in high power distance cultures high Power Distance cultures develop a fear of authority [4]. This fear of authority causes employees to remain silent and avoid communication that could challenge superiors.

In addition, many companies promote a flexible and open communication culture, hierarchical barriers still do exist. Too many layers, unclear instructions, and limited feedback channels will eventually distort information. It slows down communication, creates inefficiencies and increases the gap between the top management and staff [20].

Although there is growing research on employee silence, power distance, and psychological safety, there is limited research that studies these issues in Sri Lankan companies. Thus, this research will address this gap by examining how hierarchical communication barriers influence upward feedback and suppression of feedback in Sri Lankan companies.

3 METHODOLOGY

This study employed a qualitative research approach to examine how hierarchical communication barriers influence the suppression of upward feedback in Sri Lankan companies. A qualitative research approach was used because this study closely focuses on employee experiences, perceptions, attitudes, and feelings regarding hierarchical

structures and the communication that takes place within the organization. This study used an exploratory research design to understand the experiences of employees within high power distance organizations.

The data were collected through primary data in the form of semi-structured interviews, with informed consent obtained from participants prior to their participation. Semi-structured interviews are the most appropriate as it provides the balance between structure and flexibility. Interviews were conducted through online platforms like Microsoft Teams or in person. The duration of each interview was between 30 minutes and one hour.

This study employed a purposive sampling method to interview a sample size of 5 employees of different hierarchical levels employed at different Sri Lankan organizations. Purposive sampling is appropriate for this qualitative, exploratory study because it allows the researcher to intentionally pick employees of various hierarchical levels ranging from interns to junior-level and senior-level employees, to suit the objective of the study. For this research, the aim was to study and understand perspectives in depth rather than to produce statistics on the findings. A sample of five purposely selected participants allowed the researcher to study in-depth the diversity and richness of these different perspectives rather than representing this in numerical data. Participants are supposed to be working or have worked for Sri Lankan organizations with a proper hierarchical reporting structure.

To ensure diversity of perspectives, participants were from diverse industries such as banking, IT, logistics and real estate, as these industries collectively represent a significant portion of Sri Lanka's service sector economy [2] and share a common characteristic of rigid hierarchical reporting structures. This allowed the researcher to analyse cross-industry comparisons of how power distance manifests in communication behaviour.

Table 1 provides a summary of each participant, including their demographic and professional information, such as the industry, hierarchical position, years of experience, gender and age. This overview provided context for interpreting thematic findings and allowing patterns in the data to be considered in relation to the participants' industries and positions within the hierarchy.

Interview transcripts were analysed following the guidelines introduced by Braun and Clarke [24]. Interviews were recorded with consent of participants; transcripts transcribed using Microsoft Teams. Initial codes were generated using MAXQDA software, analysing meaningful segments related to hierarchy, communication behaviour and feedback. Codes were generated into themes based on shared patterns of meaning. Themes were created, refined and organized into a thematic structure comprising seven main themes. Similar codes were merged on MAXDQA according to its patterns of shared meaning and refined into broader thematic categories. Themes were reviewed and further merged and refined to form 7 overarching main themes and 23 subthemes. This process allowed the researcher to systematically identify recurring patterns collected across the participants while preserving each participant's contextual richness.

Table 1. Demographic details of participants

Participant No.	Industry	Position	Years of Experience	Gender	Age
Participant 1	Banking	Head	Less than 1	Male	22
Participant 2	Real Estate	Senior executive	More than 5	Male	27
Participant 3	Logistics	Intern	Less than 1	Female	20
Participant 4	IT	Associate	More than 2	Female	23
Participant 5	IT	Head of Department	More than 5	Female	34

4 FINDINGS AND DISCUSSION

The findings suggest that hierarchical communication barriers cannot be solely understood only as formal and rigid organizational structures. While hierarchy remains visible through these reporting relationships, authority and hierarchical position within the organization, participants explicitly described their communication experiences in relation to managerial trust, behaviour, openness and interpersonal relationships. This signifies that hierarchical effects are encountered in daily interactions and not through hierarchy alone.

This chapter presents the findings of the thematic analysis of the data collected from five semi-structured interviews with em-

ployees across four major industries in Sri Lanka. Interviews were coded using MAXQDA, generating 244 coded segments categorized into seven main themes (T1 to T7), each encompassing two to four subthemes (ST), bringing the total to 23 subthemes.

Table 2 describes the thematic overview of all five participants spanning from an intern to department heads, coded into seven themes, indicating that these were experienced at every point of hierarchy represented in the sample. Theme 3 describes manager behaviour, relationship, and trust, and theme 4 discusses the communication channels used in organizations, the two most populated themes asserted by the sample. Participants were concerned about their relationship with their immediate supervisors rather than the broader hierarchy.

Table 2. Thematic overview

Theme	Subthemes	Segments
T1: Hierarchy and Power Distance as a Structural Barrier	Seniority and power imbalance Cultural respect for authority Demographic and positional vulnerability	33
T2: Fear and Psychological Safety in Upward Communication	Fear of repercussions and damaged relationships Fear of judgement and criticism Self-censorship Courage and comfort to speak up	33
T3: Behaviour, Relationship and Trust of Manager	Manager openness and approachability Manager reaction to criticism Relationship quality and trust	54
T4: Communication Channels, Formality and Access	Channels and tools used Formality of organizational culture Ease of accessing hierarchical levels Cross team communication	42
T5: Formal Feedback and Organizational Trust	Types of formal feedback Feedback encouraged by management Trust in feedback process	32
T6: Consequences of Suppressed Feedback	Organizational costs Most affected party Does feedback lead to change	33
T7: Perceptions of Change and Organizational Openness	Suggested changes to reduce hierarchy driven fear Challenges or resistance to change Perceived variation in organization adaptability	17

4.1 *Theme 1: Hierarchy and Power Distance as a Structural Barrier*

Participants across industries voiced critiques of strong hierarchy, highlighting the negative impact on decision-making, competence and communication. Participant 2 stated that decision-making is immediate and effective with flexible hierarchical structures but “if it was more structured and if there was more hierarchy involved, ..., it can take two to three days, and we can lose the client”. Participant 5 offered the most in-

sightful critique where hierarchy is described as "a very outdated concept for corporate purposes ..., enforcing strict hierarchies only widens the gap in communication."

Participant 5 described the workplace culture as "a little archaic", although the formal salutations such as "Sir" and "Madam/Miss" have significantly been displaced. Participant 4 admitted that when addressing senior employees, she is "very careful of words" linking this to being unable to question their decisions. However, Participant 3 provided a counterexample, describing that in their organization, employees address each other by name, noting that this was difficult to adjust as it broke away from typical Sri Lankan culture.

Participant 5 introduced a critical subtheme where hierarchy does not affect only one's employment status, but it also intersects with an individual's gender, age, and position in the hierarchy. Participant 5 further emphasised this with the statement, "If you're a woman, that's a problem... If you're young, that's a problem... If you're an intern, you basically have no right."

4.2 *Theme 2: Fear and Psychological Safety in Upward Communication*

Participant 1 expressed that employees fear speaking up as it is perceived to be a direct threat to their relationship with the management and would risk losing future benefits. He described how a manager may "throw an employee under the bus" to protect themselves, a practice that is an accepted norm in Sri Lankan workplaces. Employees are often concerned about being seen as incompetent. This is supported by a comment stated by Participant 5, "what will they think?... am I asking a dumb question?". Participant 3 described withholding ideas in a meeting with external parties, expressing that she did not feel comfortable speaking up. Participant 5 suppressed a reaction towards an offensive situation, claiming that it was "internal anyway".

As a counter-instance, Participant 4 remarked that she feels comfortable seeking assistance from her supervisor as she trusts that he would be open and willing to listen. This highlights that trust as a managerial behaviour can eliminate the fear and silence of speaking up within the workplace.

4.3 *Theme 3: Behaviour, Relationship and Trust of Managers*

Participants 2, 3 and 5 collectively expressed that relationships with managers can shape communication within organizations. Participant 2 further described that when managers are strict or rude, employees are discouraged from providing genuine feedback, restricting upward communication. Participant 5 recounts a scenario of communicating with a non-approachable party, stating that it seemed like "having a conversation with a wall." Participants 3 and 4 described positive experiences of managers who "discussed and agreed to a common ground", leading to employees participating in the discussion and cultivating a collaborative environment. However, Participant 1 recounted a scenario where feedback is recorded as a "black mark" against employee performance, thereby affecting reputational risk. Participant 3 emphasizes that trust in supervisory relationships encourages employees to be more enthusiastic in their work, thereby resulting in organizational effectiveness. Participant 5 addresses that in Sri Lankan workplaces it is uncommon for subordinates to "grab coffee with your supervisor".

4.4 *Theme 4: Communication Channels, Formality and Access*

Participant 2 reported that he heavily relies on WhatsApp as a communication channel, highlighting informal yet rapid communication exchanges. In contrast, Participant 1 is reported to have a more formal means of communication, where employees send Outlook invitations followed by Zoom meetings to have meeting records. Participant 1 expressed that his management highly discourages discussions of personal topics. In contrast, Participant 5 described an open-door culture, cultivating an egalitarian communication environment, the principle where all employees are treated as equal and deserve equal rights and opportunities regardless of their position. Participant 5 further described a scenario of having a difficult conversation with a low-performing employee is always "taken in a personal way." Participant 3 noted that reaching senior-level employees such as the CEO or CFO is a challenge as they are located in a different building,which makes it harder to reach out to them. How-

ever, if required, feedback to the top management is escalated through the immediate supervisor. Participant 5 expressed that in Sri Lankan workplaces, senior employees often feel they must be "snobbish and unapproachable."

4.5 *Theme 5: Formal Feedback Mechanisms and Organizational Trust*

According to data, all organizations' formal HR channels have been established to gather employee feedback. Some organizations rely directly on HR contact while others use confidential portals or whistleblowing mechanisms to report feedback. Participants described this as an anonymous process, protecting employees while gathering feedback. Formal feedback channels are mostly associated with critical issues such as harassment, discomfort, fraud, etc. Participant 1 emphasized that trust depends on the immediate supervisor rather than formal channels, highlighting the importance of openness in the relationship with the immediate supervisor. However, Participant 5 noted that the management "gets in a lot of trouble" if employee sentiment is bad. This suggests organizational accountability.

4.6 *Theme 6: Consequences of Suppressed Upward Feedback*

Participants 2 and 5 highlighted organizational costs of limited upward communication. Participant 2 provided an example of a task due on Monday that cannot be solved until Wednesday, resulting in client dissatisfaction. Participant 5 strongly argued that limited upward communication is the "greatest reason for stagnant companies", further describing that the organization may be "running by default" but with no one "working towards a shared goal." There is strong consensus that the burden falls on junior employees. Participant 5 described junior employees as "the bottom of the pyramid" in the organizational hierarchy. Participant 3 linked this to the junior staff who do "more hands-on work" yet have the least influence upward. Participant 2 described a positive experience of outdated laptops being replaced after the issue was raised. In contrast, Participant 1 noted that managerial action is only temporary and issues go back to normal.

4.7 *Theme 7: Perceptions of Change and Organizational Openness*

Participant 3 argued that more frequent informal communication with supervisors reduces fear over time, as employees will become "more comfortable with their supervisors", thereby "expressing themselves more." Participant 4 suggested that these transformations could take over five years to fully embed, noting that transformational friction among employees is inevitable. Participants 2 and 5 admitted that ideas may be dismissed due to the sender's position in the organization, regardless of open policies. Participant 5 argued that change "has to come from within" rather than structural imposition.

The findings confirm that the study is grounded in Hofstede's power distance theory [5], [21]. Aligning with Sri Lanka's high PDI score [3], hierarchy emerged as a strong structural barrier which participants associated with slow decision making, communication delays and the fact that organizational hierarchy distorts information flow [14]. Furthermore, this study revealed that this barrier is intensified by gender, age, and position in the organization, in ways that Hofstede's theory does not cover [5]. Fear of authority was found to be the primary driver of the suppression of upward communication [4], this is consistent with the implicit voice theory which discusses self-censorship [19]. This was found closely with previous studies [4], where it was found that individuals with stronger power distance beliefs experienced greater fear of authority and less effective communication with superiors. This aligns with the idea that employees are less willing to provide feedback in high power distance organizations [6]. However, participants discussed counter-instances where they feel comfortable speaking up, implying that psychological safety can eliminate fear of authority [19], [22]. Although communication channels and formal feedback mechanisms were found in every organization, this does not guarantee genuine upward feedback because more than the hierarchical structures, the trust in how employee's feedback is received is what matters most [9], [15], [20]. The consequences of suppressed upward feedback include slower decision-making and strain on junior employees who are at the bottom of the organizational structure [1], [13].

The findings suggest that there are three levels of barriers, namely, cultural-structural barriers, relational barriers, and infrastructural barriers: Cultural-structural Barriers (Theme 1), Relational Barriers (Theme 3), and Infrastructural Barriers (Themes 4 and 5). Of the three barriers, relational barriers emerged as the most substantial. Participants described in-depth their supervisor attitudes and behaviour as the deciding factor when it came to speaking up. Infrastructural barriers, including formality, communication channel choice, and physical access to senior leadership, were evident across all organizations in the sample. Each organization had a method to reach any level of hierarchy, whether through direct or formal means. However, the barrier was not the availability of these channels but how messages would be perceived and the feedback received. This relates back to Theme 3, where supervisor attitudes strongly influence employee voice. These barriers lead to organizational consequences, where participants linked suppressed upward feedback to slower growth and decision-making within the organization (Theme 6). Participant 5 strongly argued that it leads to stagnation of the company with the lower-level employees bearing the brunt. Participants also admitted that having open communication policies alone are not sufficient to eliminate hierarchical fear and it only works if paired with real trust between supervisors and subordinates (Theme 7). This addresses R1: hierarchical communication barriers in this sample are not primarily structural but are validated through managerial behaviour and cultural norms of respect and authority. Formal structures operate as secondary and play a large passive role in shaping employee silence. The primary factor is relational dynamics, which includes the attitudes and responses of supervisors, that drive employee silence. Trust and interpersonal behaviour are the primary determinants.

The data identifies Fear (Theme 2) as the mechanism that links barriers to silence, consistent with the view that claims High Power Distance cultures develop a fear of authority, resulting in ineffective communication with supervisors [4], [6]. However, the counter-instances discussed in Themes 2 and 4 indicate that it is not purely based on power distance: where employees trusted their supervisor, they were willing to seek help and speak up. This is consistent with the view that employees weigh psychological safety against the value of speaking up [19]. This addresses R2: hierarchical barriers reduce willingness to provide upward feedback as it generates fear of relational and reputational damage. This fear is culturally reinforced by power distance but is moderated by the trustworthiness of the immediate supervisor, more than an employee's structural position in the hierarchy.

5 CONCLUSION

In conclusion, the findings suggest that there are three levels of barriers, namely, cultural-structural barriers, relational barriers, and infrastructural barriers: cultural barriers grounded in high power distance, relational barriers that are shaped by trust and behaviour of supervisors and infrastructural barriers that root from communication channels and accessibility of hierarchical levels. Relational barriers proved to be the most significant as power distance alone does not explain employee silence. Instead, silence is an effect of the manager's day to day behaviour. Suppressed upward feedback was linked to slower decision making and overall organizational efficiency with the junior employees being affected the most. Organizations seeking to improve must focus more on building trust between supervisors and subordinates rather than enforcing formal policies.

6 LIMITATIONS AND FUTURE RESEARCH

The study employed only five professionals across four industries, where all participants were interviewed through semi-structured interviews. While this sample size was considered appropriate given the nature of this exploratory research, which prioritized capturing in-depth insights from participants rather than statistical data, this limits how far these findings can be extended beyond these individuals and organizations. Each organization in the sample is represented by only one employee, except for IT, which represents two individuals. Future research may expand the sample size to include multiple employees from the same organization to study and compare multiple accounts of managers, not just based on one individual's

view. Future research may also include a longitudinal design that would allow for studying whether trust in a specific manager changes employees' willingness to voice over time. Future work could also test this quantitatively to study manager trust as a variable between power distance and employee voice.

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The Impact of Hotel Staff Emotional Intelligence on Guest Satisfaction in Colombo, Sri Lanka

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ABSTRACT: This study examines the relationship between guest-perceived hotel staff emotional intelligence and guest satisfaction in hotels in Colombo, Sri Lanka. Drawing on Emotional Intelligence Theory, this study investigates how guests' perceptions of hotel staff's ability to perceive, understand, and regulate emotions influence overall guest satisfaction. [1]. A quantitative research approach was adopted, and data were collected through a structured questionnaire from 100 hotel guests. Statistical analysis was conducted using SPSS, including descriptive statistics, reliability test, correlation, and regression analysis. The findings reveal a strong positive relationship between guest-perceived hotel staff emotional intelligence and guest satisfaction ($r = 0.721$, $p < 0.001$). Regression analysis further indicates that guest-perceived staff emotional intelligence was significantly associated with guest satisfaction, with the model accounting for 52% of the variance. These results highlight the relevance of emotional competencies to service quality and the emotional dimension of guest experiences within hospitality contexts. This study contributes to the limited empirical research on emotional intelligence in the Sri Lankan hospitality context by providing guest-based quantitative evidence. The findings offer practical implications for hotel management, particularly in improving staff training, recruitment, and service strategies. Limitations and directions for future research are also discussed.

Keywords: Emotional Intelligence, Guest Satisfaction, Hotels, Sri Lanka, hospitality industry

1 INTRODUCTION

The hospitality industry is inherently service driven, where employee-guest interactions play a critical role in guest experiences and satisfaction [2]. In hotel settings, frontline employees frequently engage with guests in emotionally dynamic situations, requiring them to effectively manage both their own emotions and those of others. Emotional intelligence (EI), defined as the ability to perceive, understand, and regulate emotions, has therefore become an essential competency in delivering high-quality service experiences [1].

Although emotional intelligence has been examined in hospitality contexts, recent research has addressed a range of employee and service-related outcomes. In Sri Lanka, Haritha, Siva and Sania [3] examined emotional intelligence and emotional labor among front-office employees in five-star hotels in Colombo, focusing on emotional attachment and enduring host-guest relationships. Similarly, Monil et al. [4] examined emotional intelligence among frontline hotel employees in Malaysia in relation to communication satisfaction and job performance. More recent research has also examined emotional intelligence and service quality among hospitality employees in Spain [5]. While these studies demonstrate continued interest in emotional intelligence within hospitality, they primarily examine employee perspectives or employee-related outcomes. Guest-based research by Lam,

Cheung and Lugosi [6] specifically examined guests' perceptions of frontline hotel employees' emotional intelligence and its relationship with guest satisfaction across Asian and non-Asian contexts. However, comparable guest-based quantitative evidence examining perceived hotel staff emotional intelligence and guest satisfaction within the Sri Lankan hotel context remains limited.

The aim of this study is to examine the relationship between guest-perceived hotel staff emotional intelligence and guest satisfaction in hotels in Colombo, Sri Lanka. To achieve this aim, the study is guided by the following objectives: to review the concept of emotional intelligence in the hotel context, to review the concept of guest satisfaction in the hotel industry, to examine the relationship between guest-perceived hotel staff emotional intelligence and guest satisfaction, and to provide recommendations for improving emotional intelligence and enhancing guest satisfaction in hotels.

This study is significant as it contributes to the hospitality literature by providing guest-based empirical evidence from a developing tourism context where such research remains limited. From a practical perspective, the findings offer valuable insights for hotel management in improving service quality, enhancing guest experiences, and supporting human resource development practices in a highly competitive and service-driven industry.

2 LITERATURE REVIEW

Emotional intelligence (EI) refers to an individual's ability to perceive, understand, and manage emotions in oneself and others [1]. In the hospitality industry, where service delivery involves continuous interpersonal interaction, EI is considered a critical factor influencing employee performance and customer-related outcomes. Emotionally intelligent employees are better equipped to recognize guest needs, respond empathetically, and manage service encounters effectively [7].

Guest satisfaction, on the other hand, reflects the extent to which a guest's expectations are met or exceeded during their service experience [8]. In hotel contexts, satisfaction is shaped by service quality, staff responsiveness, and emotional interactions during service delivery [9]. Since hotel services are intangible and experiential, the behavior and emotional competence of employees play a significant role in influencing guest perceptions [2].

The relationship between emotional intelligence and guest satisfaction can be theoretically understood through Emotional Intelligence Theory, which conceptualizes emotional intelligence as the ability to perceive, understand, and regulate emotions and use emotional information effectively in interpersonal interactions [1]. In hotel service encounters, these abilities may enable staff to recognize guests' emotional cues, respond appropriately to their needs, and regulate their own emotional responses during interpersonal interactions. Such emotionally responsive interactions may contribute to more favorable guest evaluations of the service experience. Empirical research has also examined this relationship in hospitality settings. Kernbach and Schutte [7] found that service provider emotional intelligence was associated with customer satisfaction through service interactions. More directly, Lam, Cheung and Lugosi [6] examined guests' perceptions of frontline hotel employees' emotional intelligence and found a positive and significant relationship between employee emotional intelligence and overall guest satisfaction across Asian and non-Asian respondents. Recent hospitality research has continued to examine emotional intelligence from different perspectives. Haritha, Siva and Sania [3], for example, found that emotional intelligence was among the factors associated with emotional labor and the development of emotional attachment and enduring relationships between hosts and guests in five-star Colombo hotels. In Malaysia, Monil et al. [4] reported significant positive relationships involving emotional intelligence, communication satisfaction and job performance among frontline hotel employees. Similarly, Alberto Sanz-García et al. [5] examined emotional intelligence and perceived quality of hospitality service among hospitality employees in Spain. However, much of this recent research focuses on employees or employee-related outcomes, while guest-based evidence examining perceived hotel staff emotional intelligence and guest satisfaction in the Sri Lankan hotel context remains limited.

Based on this theoretical and empirical evidence, this study proposes that guest-perceived hotel staff emotional intelligence is positively associated with guest satisfaction. This relationship forms the basis of the conceptual framework and hypothesis tested in the study.

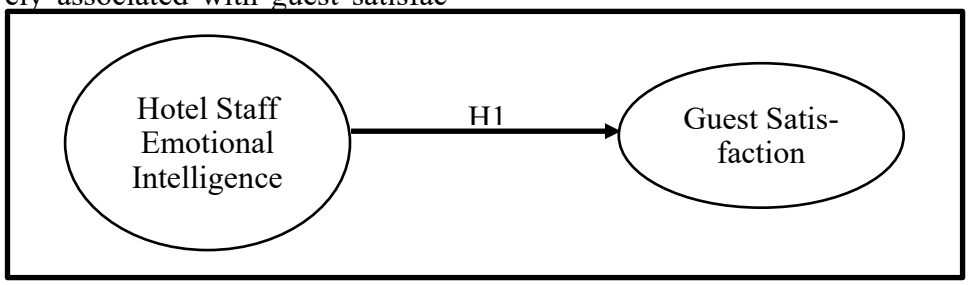


Figure 1. The conceptual model

H1: Guest-perceived hotel staff emotional intelligence is positively associated with guest satisfaction.

3 RESEARCH METHODOLOGY

This study adopts a quantitative research methodology within a deductive approach to examine the relationship between guest-perceived hotel staff emotional intelligence and guest satisfaction. The deductive approach is appropriate as it allows the testing of hypotheses derived from existing theory, specifically Emotional Intelligence Theory [10].

A survey strategy was employed to collect data from hotel guests in Colombo, Sri Lanka. The use of a structured questionnaire enabled the collection of standardized responses, ensuring consistency and reliability in data analysis [10]. The questionnaire was adopted from Lam et al. [6], with minor modifications to align with the scope of the present study. Emotional intelligence was measured using seven items developed Lam, Cheung and Lugosi [6] based on the theoretical dimensions of the Wong and Law Emotional Intelligence Scale (WLEIS), namely others' emotional appraisal, utilization of emotion, and regulation of emotion [11]. Lam, Cheung and Lugosi [6] established the reliability and construct validity of these measures through exploratory and confirmatory factor analyses. Although the seven emotional intelligence items reflect these different theoretical dimensions, the study analyzed emotional intelligence as a single overall construct rather than examining each dimension separately. Guest satisfaction was measured using two items adopted from the same study [6].

The target population comprised hotel guests who had stayed at hotels in Colombo, Sri Lanka, as these respondents had direct experience with hotel service encounters and were therefore able to evaluate staff emotional intelligence and their own satisfaction. As no sampling frame of hotel guests in Colombo was available, a non-probability sampling approach was adopted. Convenience sampling was used to recruit 100 respondents who met the study criteria, and data were collected through an online questionnaire. The sample size exceeded the minimum suggested by Green's [12] rule of thumb for regression analysis, $N \geq 50 + 8m$, where m represents the number of predictors. With one predictor, the minimum suggested sample size was 58, while the study obtained 100 responses. The use of convenience sampling limits the generalizability of the findings and is therefore acknowledged when interpreting the results [10].

Data were analyzed using SPSS software. Descriptive statistics were used to summarize the data, while reliability was assessed using Cronbach's alpha. Correlation analysis was conducted to examine the strength and direction of the relationship between variables. Prior to regression analysis, assumptions of linearity, normality, homoscedasticity, and independence were assessed using residual plots, the normal probability plot, histogram, and Durbin-Watson statistic. Potential influential observations were also examined using standardized residuals and Cook's distance. Simple linear regression was then conducted to examine the association between guest-perceived hotel staff emotional intelligence and guest satisfaction [10].

Ethical considerations were strictly followed, including informed consent, anonymity, and confidentiality of participants.

4 ANALYSIS, FINDINGS, AND DISCUSSION

Table 1. Descriptive statistics

Variables' Items	Mean	Standard Deviation
IV – Emotional Intelligence		
Others' emotional appraisal (OEA)		
1) The hotel employee knew my emotions based on my behaviors.	3.62	.838
2) The hotel employee was sensitive to my feelings and emotions.	3.71	.808
3) The hotel employee had good understanding of my emotions.	3.59	.780
Utilization of emotion (UOE)		
4) The hotel employee was self-motivated to serve me.	3.91	.683
5) The hotel employee had tried the best to serve me.	3.98	.791
Regulation of emotion (ROE)		
6) The hotel employee was able to control temper and handle difficulties rationally.	3.92	.662
7) The hotel employee had good control of the emotions.	3.85	.716
DV – Guest Satisfaction		
8) I am satisfied with the employee's emotional performance in the service encounter.	3.95	.626
9) I am overall satisfied with the customer services of the hotel.	4.08	.646

Descriptive statistics indicate that respondents generally reported positive perceptions of hotel staff emotional intelligence and satisfaction levels, with mean values above 3.5 across all items.

Table 2. Reliability analysis

Variable	Cronbach's Alpha	N of Items
Emotional Intelligence	.841	7
Guest Satisfaction	.653	2

Reliability analysis indicated good internal consistency for emotional intelligence (Cronbach's $\alpha = 0.841$), while guest satisfaction showed relatively lower internal consistency ($\alpha = 0.653$). Although this value is below the conventional threshold of 0.70, lower alpha values can occur with scales containing few items [13]. The guest satisfaction measure consisted of two items adopted from a previously validated hospitality instrument [6], and the inter-item correlation of 0.485 further indicated a meaningful relationship between the two items.

Table 3. Correlation analysis

Correlations			
		EI_mean	GS_mean
EI_mean	Pearson Correlation	1	.721**
	Sig. (2-tailed)		<.001
	N	100	100
GS_mean	Pearson Correlation	.721**	1
	Sig. (2-tailed)	<.001	
	N	100	100
**. Correlation is significant at the 0.01 level (2-tailed).			

Correlation analysis revealed a strong positive relationship between guest-perceived staff emotional intelligence and guest satisfaction ($r = 0.721$, $p < 0.001$), indicating that higher levels of perceived emotional intelligence are associated with greater guest satisfaction.

Prior to interpreting the regression results, diagnostic tests were conducted to assess the underlying regression assumptions. Visual inspection of the histogram and normal P-P plot indicated that the residuals were approximately normally distributed. The scatterplot of standardized predicted values against standardized residuals showed no clear systematic pattern or funnel shape, supporting linearity and homoscedasticity. The Durbin-Watson statistic was 1.885, indicating acceptable independence of the residuals. Two observations had standardized residuals slightly beyond ±3; however, the maximum Cook's distance was 0.101, indicating that no observations exerted substantial influence on the regression model [10].

Table 4. Regression analysis and hypothesis testing

Coefficients[a]								
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	R	R Square	Adjusted R Square
	B	Std. Error	Beta					
1 (Constant)	1.243	.272		4.571	<.001	.721[a]	.520	.515
EI_mean	.730	.071	.721	10.297	<.001			
Predictors: (Constant), EI_mean								
Dependent Variable: GS_mean								

H1: Supported

The regression results indicated a statistically significant positive association between guest-perceived hotel staff emotional intelligence and guest satisfaction ($B = 0.730$, $\beta = 0.721$, $t = 10.297$, $p < 0.001$). The model explained 52% of the variance in guest satisfaction ($R^2 = 0.520$). Therefore, H1 was supported, indicating that higher levels of guest-perceived hotel staff emotional intelligence were significantly associated with higher guest satisfaction in the sample.

These findings are consistent with previous studies. Lam, Cheung and Lugosi [6] also identified a strong positive relationship between employees' emotional intelligence and guest satisfaction, with a high explanatory power ($R^2 = 0.605$). Similarly, Kernbach and Schutte [7] found a significant main effect of service-provider emotional intelligence on customer satisfaction, with a large effect size ($\eta^2 = 0.44$). Customer satisfaction differed across low ($M = 4.16$, $SD = 0.68$), medium ($M = 3.12$, $SD = 0.80$), and high ($M = 2.68$, $SD = 0.80$) levels of service-provider emotional intelligence, with lower scores indicating greater satisfaction. These findings support the relevance of emotional intelligence to customer evaluations of service interactions, while the present study extends this evidence to a guest-based hotel context in Colombo, Sri Lanka.

The findings are consistent with Emotional Intelligence Theory, as the emotional abilities represented in the overall EI construct provide a theoretical basis for effective interpersonal interactions during hotel service encounters. From a guest perspective, staff who recognize emotional cues, respond appropriately to guest needs, and regulate their own emotional responses may create interactions that are evaluated more favorably. This provides a possible theoretical explanation for the observed positive association between guest-perceived staff emotional intelligence and guest satisfaction, particularly in high-contact hospitality environments where emotional interactions form an important part of service encounters [1].

Furthermore, respondents reported consistently positive perceptions across the theoretical dimensions of emotional intelligence, namely others' emotional appraisal (OEA), utilization of emotion (UOE), and regulation of emotion (ROE). Although these dimensions were not examined separately in the inferential analysis, the descriptive findings are consistent with the theoretical structure proposed by Wong and Law [11]. The results therefore support interpretation of emotional intelligence as an overall construct in the present study, while the relative contribution of individual EI dimensions to guest satisfaction remains an area for future research.

Overall, the findings indicate that guests' perceptions of hotel staff emotional intelligence are significantly associated with how hotel service experiences are evaluated within the Sri Lankan hospitality context.

5 CONCLUSION, IMPLICATIONS, LIMITATIONS AND FUTURE RESEARCH

This study examined the relationship between guest-perceived hotel staff emotional intelligence and guest satisfaction in Colombo, Sri Lanka, and found a significant positive association between the two variables.

The findings highlight important managerial implications, suggesting that hotels should prioritize emotionally responsive service behaviors and emotional intelligence-related competencies in staff training, recruitment, and performance evaluation to enhance service quality and guest experiences. The findings also emphasize the growing importance of emotional competencies in modern hospitality environments, particularly in culturally diverse and service-intensive contexts such as Colombo.

However, the study has several limitations. The use of convenience sampling and a relatively small sample size may limit the generalizability of the findings. Additionally, the cross-sectional design does not capture changes over time.

Future research could adopt larger and more diverse samples, explore additional variables, and utilize longitudinal designs to provide deeper insights into the relationship between emotional intelligence and guest satisfaction.

Overall, the findings highlight guest-perceived hotel staff emotional intelligence as an important interpersonal capability associated with how guests evaluate service

experiences within the Sri Lankan hospitality context.

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When Meaning Breaks: Cognitive Ambiguity, Film Literacy, and Culturally Situated Interpretation of Open-Ended Abstract Cinema Among Sri Lankan Audiences

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ABSTRACT: Abstract cinema departs from conventional narrative structures by disrupting linear storytelling, causal continuity, and narrative closure, requiring audiences to actively construct meaning from fragmented audio-visual elements. This qualitative study explores how Sri Lankan audiences cognitively and emotionally interprets an open-ended abstract short film and examines the psychological factors underlying differing interpretations. Guided by cognitive film theory, Gestalt principles, embodied film experience, and reception theory, the study adopted a single-artifact qualitative reception design. Data was collected through two focus group discussions with general and film-literate viewers and four semi-structured interviews with film professionals and academics (N = 14). Reflexive thematic analysis identified six themes: active cognitive construction, ambiguity as engagement and barrier, film literacy as an interpretive gateway, cultural and religious frameworks, audiovisual form as a meaning-making system, and psychological projection. The findings reveal that audience responses to ambiguity are shaped by the interaction of cognitive processing, film literacy, and cultural schemas. Viewers with greater interpretive competence engaged in symbolic decoding and reflection, whereas those with limited interpretive resources were more likely to experience confusion or simplified interpretations. The study proposes a culturally grounded model of abstract-film reception, demonstrating how cognitive, cultural, and experiential factors jointly shape meaning-making. These findings contribute to cognitive film theory and reception studies by offering new insights into audience engagement with abstract cinema in the Sri Lankan context.

Keywords: Abstract cinema, Audience reception, Cognitive film theory, Film literacy, Meaning making, Reflexive thematic analysis, Sri Lankan audiences

1 INTRODUCTION

Cinema is frequently understood as a medium through which stories, emotions, and ideas are communicated to audiences. Yet the experience of watching a film is not limited to the passive reception of information. Spectators actively organize perceptual stimuli, infer causal relationships, form hypotheses, draw upon memory, evaluate emotional cues, and construct meaning from the audiovisual material presented to them. Cognitive approaches to film therefore position the spectator as an active participant in the production of cinematic meaning rather than as a passive recipient of an already completed message [1] [2].

In conventional narrative cinema, this meaning-making process is supported by a relatively stable set of formal conventions. Continuity editing, causal progression, temporal ordering, character motivation, and narrative closure provide spectators with cues through which fragmented audiovisual information can be organized into coherent event structures. Such conventions reduce uncertainty and facilitate the construction of

stable mental models of cinematic events [3] [4].

Open-ended abstract cinema presents a different cognitive environment. Rather than providing a clear causal sequence, such films may employ fragmented imagery, symbolic representation, nonlinear temporality, minimal dialogue, disrupted continuity, and unresolved conclusions. These formal strategies weaken the narrative cues through which audiences ordinarily construct coherence. Consequently, spectators may be required to infer relationships between disconnected events, identify patterns among recurring symbols, interpret audiovisual form, and construct meanings that remain fundamentally uncertain.

The interpretive difficulty of abstract cinema is therefore not simply a matter of whether audiences "understand" a film. It involves a complex interaction between perception, attention, memory, inference, emotion, prior knowledge, and cultural experience. Cognitive film theory provides a valuable framework for understanding this process because it conceptualizes spectators as active meaning-makers who construct and revise interpretations through inferential activity [1]. Similarly, the Scene Perception and Event Comprehension Theory (SPECT) emphasize the interaction between perceptual processing and the construction of event models during visual narrative comprehension [4]. When conventional cinematic cues are weakened, however, the processes through which spectators construct coherence may become unstable.

Gestalt-oriented approaches to film experience offer another important perspective. Human perception tends to organize fragmented stimuli into meaningful wholes, seeking patterns, continuity, and closure [5]. Abstract cinema may deliberately interfere with these tendencies by withholding information or presenting visual and temporal relationships that resist straightforward organization. The resulting tension between the spectator's desire for coherence and the film's resistance to closure may be central to the psychological experience of abstract cinema.

At the same time, interpretation is not solely determined by the formal properties of a film. Audiences encounter cinematic texts with pre-existing cultural knowledge, religious beliefs, personal memories, emotional experiences, and learned interpretive strategies. Reception-oriented approaches therefore emphasize that meaning emerges through the interaction between texts and audiences within specific social and cultural contexts. The same symbol may generate substantially different interpretations depending on the cultural and ideological frameworks through which it is encountered.

This issue is particularly relevant in Sri Lanka, where cinema is experienced within a culturally plural environment shaped by Buddhist, Hindu, Christian, and Islamic traditions, alongside diverse linguistic, social, educational, and historical experiences. Yet empirical research examining how Sri Lankan audiences cognitively process abstract and open-ended cinema remains limited.

The present study addresses this gap by examining how Sri Lankan audiences interpret an open-ended abstract short film and how psychological, cognitive, cultural, and educational factors influence their interpretive processes. Rather than treating ambiguity as an inherent weakness of abstract cinema, the study asks whether ambiguity can function simultaneously as an invitation to deeper engagement and as a threshold beyond which audiences experience cognitive difficulty or withdrawal.

The study was guided by three research questions:

1. How do Sri Lankan audiences cognitively interpret open-ended abstract films?
2. How do social and cultural backgrounds influence patterns of interpretation?
3. What psychological factors contribute to over-interpretation or under-interpretation of open-ended abstract films?

The central argument developed from the findings is that cinematic ambiguity functions as a cognitive threshold rather than a uniform interpretive condition. Within the present sample, ambiguity appeared to support deeper interpretive engagement for some participants while contributing to confusion or withdrawal for others, depending partly on their available interpretive resources and cultural experience.

The study therefore contributes a culturally situated account of abstract-film reception in which cognitive processing, film literacy, and cultural schemas operate as interconnected dimensions of meaning construction.

2 LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 *Cognitive Film Theory and the Active Spectator*

Cognitive film theory conceptualizes film viewing as an active process involving perception, inference, hypothesis formation, and meaning construction. Rather than assuming that meaning is simply transmitted from filmmaker to spectator, cognitive approaches examine the mental processes through which viewers organize cinematic information and construct interpretations [1].

Film spectators continuously generate hypotheses about what they see. They attempt to understand characters, infer motivations, establish causal relationships, anticipate future events, and revise interpretations when new information becomes available. Editing, framing, sequencing, and sound therefore influence not only what viewers perceive but also how they organize and interpret information.

Abstract cinema creates a particularly interesting environment for cognitive film theory because many of the cues that ordinarily support interpretation may be weakened or intentionally disrupted. When causality is unclear, temporal order is fragmented, or symbolic imagery replaces explicit exposition, spectators may struggle to construct stable event models. The resulting interpretive process may involve repeated hypothesis formation and revision without reaching definitive closure.

This suggests that abstract cinema does not eliminate cognitive activity; rather, it may intensify it.

2.2 *Event Segmentation and the Problem of Coherence*

happening and how different events relate to one another [3] [4].

SPECT further emphasizes the relationship between scene perception, attention, and event comprehension. Visual information is initially processed perceptually and subsequently integrated into higher-level event models that allow viewers to maintain coherence across time [4]

Abstract cinema may disrupt this process. Abrupt transitions, temporal discontinuity, symbolic substitutions, and fragmented editing can make it difficult for spectators to determine whether two scenes belong to the same event, whether an image represents reality or subjective experience, or whether a sequence should be understood literally or metaphorically.

This instability potentially increases cognitive effort. Viewers may repeatedly attempt to connect scenes and establish relationships between events, producing what may be understood as interpretive labor.

2.3 *Gestalt Perception, Closure, and Fragmentation*

Gestalt psychology emphasizes the human tendency to organize separate perceptual elements into coherent wholes. In film experience, this tendency can contribute to the perception of continuity, unity, and meaningful form [5].

Abstract cinema is particularly relevant to this framework because it may intentionally disrupt perceptual closure. Fragmented images and incomplete narrative information invite spectators to complete patterns and construct relationships that are not explicitly provided.

This creates an important paradox. The more strongly spectators seek coherence, the more actively they may interpret ambiguous material. However, when no stable interpretation can adequately organize the available information, the search for closure may become psychologically frustrating.

The same perceptual tendency that generates interpretive engagement may therefore also contribute to over-interpretation.

2.4 *Emotion, Embodied Experience, and Interpretation*

Film interpretation is not exclusively intellectual. Emotional appraisal is integrated into the process through which spectators understand cinematic events and assign significance to them [2].

Embodied approaches further suggest that film experience involves the simulation of observed actions, movements, and emotions, connecting perception with bodily and affective experience [6] [7], Audiovisual form - including sound, rhythm, lighting, framing, and movement-can therefore communicate emotional meaning even when narrative information remains uncertain.

This is especially relevant to abstract cinema. When conventional narrative [6] cues

are unavailable, spectators may use affective responses as interpretive evidence. Anxiety may be interpreted as evidence of psychological instability within the film; sadness may encourage interpretations involving loss; curiosity may signal that an unresolved symbolic relationship is significant.

Emotion therefore becomes not merely an outcome of interpretation but a mechanism through which interpretation occurs.

2.5 *Film Complexity and Interpretive Flexibility*

Complex cinematic structures can increase demands on attention, working memory, and inferential reasoning. At the same time, exposure to complexity may encourage viewers to consider multiple perspectives and meanings, potentially supporting interpretive flexibility [8].

This duality is central to the present research. Complexity can produce intellectual stimulation, but it can also create cognitive strain. The psychological effect of ambiguity may therefore depend partly on the relationship between the complexity of the cinematic stimulus and the interpretive resources available to the viewer.

2.6 *Film Literacy as Interpretive Competence*

Film literacy can be understood as the viewer's ability to recognize and interpret cinematic form, narrative structures, symbolic elements, and audiovisual information. From a cognitive film theory perspective, spectators actively construct meaning through inferential reasoning, prior knowledge, memory, and interpretive frameworks rather than simply receiving a fixed meaning from the film [1] [9].

Therefore, previous exposure to cinematic conventions and knowledge of film language may influence how audiences approach complex or ambiguous films.

A film-literate spectator may possess interpretive schemas that help them recognize symbolic imagery, fragmented editing, nonlinear structures, and open-ended conclusions as possible intentional cinematic strategies. Rather than expecting every narrative element to provide a direct explanation, such viewers may be more willing to generate hypotheses and consider multiple possible meanings. [1] emphasizes the active role of the spectator in constructing and revising interpretations, which provides a useful theoretical basis for understanding film literacy as an interpretive resource.

This is particularly relevant to abstract cinema, where conventional narrative guidance may be limited. Film literacy may therefore function as a cognitive resource that supports audiences in organizing ambiguous information and sustaining interpretation when immediate narrative clarity is unavailable. In this study, this concept is important because differences in cinematic knowledge and interpretive experience may contribute to differences in how viewers respond to ambiguity, symbolism, and open-ended meaning.

2.7 *Reception Theory and Cultural Meaning*

Reception theory emphasizes that meaning is not necessarily fixed within a cinematic text but emerges through the interaction between the text and its audience [10] [11]. Audiences actively negotiate meaning through culturally situated frameworks, and their interpretations may be influenced by social experience, symbolic traditions, existing knowledge, and narrative conventions. [10] encoding/decoding model particularly highlights the active role of audiences in interpreting media messages according to their own cultural and social positions. [11] Similarly emphasizes that reception and interpretation are historically and socially conditioned rather than completely universal. This perspective is particularly relevant to abstract cinema because ambiguous symbols and incomplete narrative information may encourage viewers to rely more strongly on their existing cultural and personal frameworks when constructing meaning.

Within the Sri Lankan context, audiences may interpret ambiguous cinematic elements through culturally familiar religious symbolism, folklore, moral narratives, and social experiences. These culturally embedded schemas can influence how viewers assign meaning to symbols, understand narrative ambiguity, and evaluate the coherence of an open-ended film. Therefore, cultural background may not simply influence *what* audiences interpret, but also *how* they construct and negotiate meaning.

Reception theory consequently complements cognitive film theory in this study.

While cognitive approaches explain the mental processes involved in constructing meaning, reception theory helps explain how culturally situated experiences and frameworks influence the meanings audiences ultimately construct [10] [11].

2.8 *Research Gap and Conceptual Proposition*

The existing literature provides valuable accounts of cognitive film processing, perceptual organization, event comprehension, emotional engagement, and audience reception. However, these dimensions are often examined separately.

Less attention has been given to how these processes interact when viewers encounter cinema that deliberately destabilizes narrative coherence, particularly within culturally specific non-Western contexts.

The present study addresses this gap by proposing that abstract-film interpretation can be understood through three interacting systems:

Cognitive processing
→ perception, inference, event construction, pattern recognition

Interpretive resources
→ film literacy, prior knowledge, ambiguity tolerance

Cultural-emotional schemas
→ religion, personal memory, emotional experience, cultural identity

These systems interact with the level of cinematic ambiguity to produce two broad interpretive trajectories:

Interpretive expansion
→ symbolic decoding → reflection → multiple hypotheses → philosophical engagement

Cognitive withdrawal
→ confusion → cognitive overload → simplified interpretation → disengagement

The study's findings suggest that ambiguity itself is therefore not necessarily the cause of interpretive failure. Rather, ambiguity may operate as a threshold condition that exposes differences in viewers' cognitive and cultural resources.

3 METHODOLOGY

3.1 *Research Design*

The study adopted a qualitative interpretivist research design. A qualitative approach was appropriate because the research sought to understand subjective experiences of cinematic interpretation rather than produce statistically generalizable measurements.

The study employed a single-artifact qualitative reception design centered on an original abstract short film created by the researcher. The artifact was designed specifically as a research stimulus and incorporated characteristics associated with cinematic ambiguity, including nonlinear narrative structure, symbolic imagery, minimal dialogue, disrupted temporal continuity, fragmented audiovisual sequences, and an open-ended conclusion. The research was theoretically informed by cognitive film theory, event segmentation, Gestalt-oriented approaches to film perception, emotional appraisal, embodied approaches to film experience, and reception theory.

3.2 *Research Artifact*

The research film functioned as a cognitive and interpretive stimulus rather than as an object whose aesthetic quality was evaluated. The film deliberately avoided conventional exposition and linear storytelling. Meaning was communicated primarily through visual composition, editing rhythm, sound design, symbolic repetition, and fragmented audiovisual structures. The conceptual foundation of the film was connected to existential and psychological themes concerning consciousness, human perception, and uncertainty. Participants were not informed in advance that they would be viewing an "abstract" or "open-ended" film. Instead, the work was introduced simply as a short film created for research purposes. This neutral presentation was intended to reduce priming effects and allow participants to form interpretations without being given a predetermined interpretive framework.

3.3 *Participants and Sampling*

Purposive sampling was used to recruit adult participants aged 18 years or above who could understand Sinhala or English and who represented varying levels of exposure to cinema. Participants with professional or academic expertise in film were recruited for expert interviews.

The final sample consisted of 14 participants:

– Six general-audience participants;
– Four film-literate participants;
– Four film professionals or academics.

The general-audience group included two male and four female participants. The film-literate group consisted of four male participants, while all four experts were male. Participants were between 18 and 40 years of age.

The sample was not intended to represent the Sri Lankan population statistically. Instead, the comparative structure enabled examination of differences in interpretive strategies associated with varying degrees of film knowledge and expertise.

For the purposes of this study, "film-literate" refers to participants with prior formal or substantial experiential exposure to film studies, filmmaking, film analysis, or related cinematic practices. Participants in this category were selected based on their demonstrated familiarity with cinematic terminology, film form, narrative structure, symbolism, and analytical approaches to audiovisual texts. This classification was used as a comparative analytical category rather than as a standardized measure of individual cognitive ability or interpretive competence.

Participant ID	Group	Gender	Language Used
GA01	General	Female	English
GA02	General	Female	English
GA03	General	Female	English
GA04	General	Female	English
GA05	General	Male	English
GA06	General	Male	English
FL01	Film-literate	Male	English
FL02	Film-literate	Male	English
FL03	Film-literate	Male	English
FL04	Film-literate	Male	English
EX01	Expert	Male	English
EX02	Expert	Male	English
EX03	Expert	Male	English
EX04	Expert	Male	English

3.4 *Data Collection*

Participants first viewed the research film without prior interpretive explanation. They were subsequently invited to discuss their understanding of the film, perceived meanings, emotional responses, moments of confusion, and interpretive strategies. Two focus group discussions were conducted: one with general-audience participants and another with film-literate participants. The focus group format allowed participants to negotiate, challenge, and develop interpretations collectively. Four semi-structured interviews were conducted with film experts. These interviews explored cognitive interpretation, psychological challenges, interpretive reasoning, abstraction, and the role of cinematic form.

All data-collection sessions were conducted in English. Participants were given the opportunity to express their interpretations, perceptions, and responses in English throughout the focus group discussions and expert interviews. As all responses were collected in English, no translation from Sinhala or other languages was required for the analysis or presentation of participant quotations.

3.5 *Data Analysis*

The data were analyzed using thematic analysis based on the framework developed by Braun and Clarke [12]. The analytical process involved familiarization with the data, initial coding, searching for themes, reviewing themes, defining and naming themes, and producing the final analytical account. The analysis was theoretically informed while remaining responsive to patterns emerging from participant responses. Initial patterns were identified from participant accounts and subsequently interpreted through cognitive and reception-oriented frameworks.

The final analysis generated six themes:

1. Interpretation as active cognitive construction;
2. Ambiguity as engagement and cognitive barrier;
3. Film literacy and knowledge networks;
4. Cultural and religious frameworks in interpretation;
5. Audiovisual form and symbolic meaning-making;
6. Psychological projection and self-reflection.

3.6 *Trustworthiness and Ethics*

Credibility was strengthened through comparison across three participant categories: general audiences, film-literate audiences, and experts. Transferability was supported through contextual description of the participants and research conditions.

Dependability was enhanced through consistent screening procedures, standardized discussion guides, and systematic thematic analysis. Confirmability was addressed through reflexive awareness of the researcher's role as both filmmaker and researcher.

Participants provided informed consent and were informed of their right to withdraw. Confidentiality and anonymity were maintained through participant codes or pseudonyms. Data were stored securely, and participants were informed that they could discontinue participation if the film caused discomfort or distress.

Because the research artifact was created by the researcher, the study involved a dual researcher–filmmaker position. This position provided a reflexive opportunity to compare the film's intended conceptual direction with meanings generated by participants; however, it also created the possibility that the researcher's prior knowledge of the artifact could influence interpretation of the data. To address this, participant accounts were treated as the primary empirical evidence, while theoretical interpretations were developed separately through the thematic-analysis process and continually considered in relation to the participants' actual responses.

4 FINDINGS

4.1 *Interpretation as Active Cognitive Construction*

The first major finding was that participants across all groups engaged in active meaning construction. Even when participants described the film as confusing, they rarely treated it as meaningless. Instead, they attempted to connect scenes, interpret symbols, infer psychological states, and construct explanations.

General-audience participants frequently relied on emotional and existential frameworks. One participant interpreted the protagonist as being psychologically consumed by his work:

"I knew he was going through something… he was getting consumed by his work… it was really affecting him deeply."

Another interpreted the film through grief and existential uncertainty:

"I think it's about dealing with grief… being lost in the world and trying to make sense of life."

These responses demonstrate that viewers constructed meaning by drawing upon familiar psychological and emotional schemas.

Film-literate participants demonstrated a different interpretive strategy. Rather than concentrating primarily on psychological realism, they classified genre, identified symbolism, and considered philosophical implications. One participant described the film as a hybrid cinematic experience that appeared to move between drama, thriller, and science fiction.

Another described the film as:

"a meditative journey into the nature of consciousness… what it means to be human."

The metaphor of the film as a puzzle was also significant:

"This movie… is kind of a puzzle… which you have to solve."

This suggests that film-literate participants possessed interpretive schemas that allowed them to approach ambiguity as a deliberate aesthetic structure.

Experts similarly characterized abstract cinema as an active process of decoding. One expert described the experience as neither purely narrative nor purely emotional but as a form of analytical engagement.

Across all groups, the fundamental pattern was therefore consistent: viewers actively constructed meaning. The major difference concerned the resources through which that construction occurred.

General audiences relied more heavily on emotional familiarity and personal experience, whereas film-literate viewers relied more heavily on cinematic knowledge, symbolism, genre awareness, and conceptual frameworks.

4.2 *Ambiguity as Engagement and Cognitive Barrier*

The second theme revealed the central paradox of abstract cinema: ambiguity can simultaneously attract and repel the spectator.

General-audience participants frequently experienced uncertainty as both curiosity and anxiety. One participant stated:

"It leaves room for you to think about it after you watch it."

Here, ambiguity extended the interpretive experience beyond the film itself.

At other moments, however, uncertainty became frustrating. A participant identified the cancer diagnosis sequence as particularly confusing, suggesting that certain narrative elements could not be integrated into a stable mental model.

Another participant described feeling:

"Curious… anxious."

This combination is theoretically significant. Ambiguity did not simply produce negative confusion. It generated an unstable emotional state in which uncertainty encouraged both attention and discomfort.

Participants also described attempting to connect scenes:

"I tried to connect with the previous and the next scenes and try to interpret what that scene meant."

This demonstrates active cognitive compensation. When conventional narrative connections were absent, viewers attempted to construct them themselves.

Film-literate participants displayed greater tolerance for uncertainty. Rather than treating ambiguity as evidence of narrative failure, they interpreted it as intentional design.

One participant suggested that the film:

"never tried to confine itself to a single genre… it let the story breathe beyond those conventional labels."

Experts similarly emphasized subjectivity and interpretive plurality.

The findings therefore indicate that ambiguity is not inherently engaging or alienating. Its psychological effect depends upon the viewer's interpretive readiness.

This leads to the study's central proposition: ambiguity functions as a cognitive threshold.

Below this threshold, viewers may experience confusion, cognitive overload, and withdrawal.

At or beyond this threshold, viewers may experience curiosity, symbolic exploration, and interpretive expansion.

4.3 *Film Literacy as a Cognitive Gateway*

Film literacy emerged as one of the clearest differences between participant groups.

General-audience participants frequently acknowledged uncertainty when encountering unfamiliar scientific, philosophical, or symbolic concepts. One participant stated:

"I don't know enough about these concepts… so I was curious… and I was anxious."

By contrast, film-literate participants integrated external knowledge into their interpretations. References to scientific theories, genre conventions, cinematic structures, and symbolism provided additional cognitive resources for constructing meaning.

An expert described film literacy as:

"It's not about watching. It's about film reading… interpreting each moment… each scene, each shot."

This distinction is central to study. Film literacy did not merely give participants more information about cinema. It appeared to change the strategy of perception itself.

Film-literate viewers were more likely to:

– search for symbolic relationships;
– interpret genre hybridity;
– analyze audiovisual form;
– tolerate unresolved narrative structures;
– consider multiple possible meanings;
– interpret ambiguity as intentional.

General audiences, in contrast, more frequently sought emotional or narrative coherence.

The findings therefore suggest that film literacy functions as a cognitive gateway mechanism. It may enable spectators to transform ambiguity from a problem requiring resolution into an interpretive resource.

4.4 *Cultural and Religious Frameworks as Interpretive Filters*

The fourth theme concerned the role of cultural and religious frameworks.

Participants frequently interpreted the film through concepts associated with spirituality, existentialism, death, rebirth, and religious symbolism.

One film-literate participant interpreted the title "Trinity" through Christian theology:

"I'm personally Christian… Trinity… God, the Son and the Holy Spirit."

Experts similarly emphasized the role of religion in shaping interpretation, noting that symbols can activate different cultural narratives.

The findings demonstrate that audiences do not encounter ambiguous symbols without prior frameworks. Instead, cultural knowledge provides interpretive anchors.

Importantly, these frameworks operated differently across participant groups.

General audiences often used culture as emotional grounding. Film-literate viewers used cultural knowledge as a symbolic decoding system. Experts interpreted cultural frameworks as unavoidable structures through which viewers construct meaning.

Thus, cultural context did not simply influence *what* audiences interpreted. It influenced *how* they interpreted.

This finding supports reception-oriented approaches while also extending them into the cognitive domain. Cultural frameworks can function as cognitive resources that compensate for missing narrative information.

4.5 *Audiovisual Form as a Meaning-Making System*

A fifth theme concerned the importance of audiovisual form.

Participants repeatedly emphasized cinematography, lighting, sound design, editing rhythm, and symbolic composition.

One general-audience participant noted being drawn into the film through:

"the visual cinematography, sounding and acting."

Another interpreted changing lighting on the protagonist's face as a representation of his psychological condition:

"Different lights were showing at his face… he was just zoning out… it kind of showed his life."

Film-literate participants analyzed sound and music more explicitly. One described sound as particularly important to the film's conceptual experience, while another emphasized how the score elevated the emotional atmosphere.

Experts similarly described the film as a form of "visual essay," emphasizing that cinematic form itself could operate as an argument.

These findings demonstrate that narrative comprehension is not the only pathway to cinematic meaning. When causal clarity is reduced, audiovisual form can become an alternative meaning-making system.

Lighting may communicate psychological instability.

Sound may suggest conceptual associations.

Editing rhythm may generate emotional tension.

Symbolic repetition may establish thematic relationships.

The film therefore communicates not only through what happens but through how audiovisual elements are organized.

4.6 *Psychological Projection and Self-Reflection*

The sixth theme revealed the most intimate dimension of abstract-film reception.

Participants frequently connected the film with personal memories, grief, anxiety, trauma, and existential reflection.

One participant stated:

"It reminds me what I went through in my life as well… I also have gone through a loss."

Another described personal memories resurfacing:

"All the near-death experiences… came rushing back… I felt the same as the character."

Film-literate participants described this process more metaphorically:

"This film… felt like holding a mirror to myself."

These responses suggest that ambiguity creates psychological space for projection.

When the film does not determine a single meaning, spectators may insert meanings drawn from their own experiences.

The film therefore becomes a psychological mirror.

This does not mean that viewers simply misunderstand the film. Rather, personal projection becomes one of the mechanisms through which abstract meaning is produced.

The expert interviews reinforced this point. Experts noted that audiences may identify symbolic meanings that were not necessarily intended by the filmmaker.

The implication is significant: the interpretive life of an abstract film may exceed its production history.

5 DISCUSSION

The findings demonstrate that abstract-film interpretation is best understood not as a binary distinction between "understanding" and "not understanding," but as a dynamic cognitive process in which audiences continuously negotiate uncertainty.

The study's central contribution is the proposition that ambiguity functions as a cognitive threshold.

This concept develops from the observation that the same abstract cinematic structure generated markedly different responses. General audiences often experienced uncertainty as anxiety or confusion while continuing to search for meaning. Film-literate participants were more likely to perceive the same uncertainty as deliberate aesthetic design. Experts emphasized that ambiguity is intrinsic to symbolic and abstract interpretation.

Therefore, ambiguity alone cannot explain interpretive outcomes.

Instead, interpretive outcomes emerge from the interaction between:

1. The degree of cinematic ambiguity;
2. The viewer's film literacy;
3. Prior knowledge and conceptual networks;
4. Cultural and religious schemas;
5. Emotional and autobiographical experience;
6. Tolerance for interpretive uncertainty.

This can be conceptualized as follows:

Cinematic Ambiguity → Cognitive Demand → Interpretive Threshold

Available Interpretive Resources > Cognitive Demand
→ Interpretive Expansion

Cognitive Demand > Available Interpretive Resources
→ Cognitive Withdrawal

This model contributes to cognitive film theory by suggesting that ambiguity is not merely an aesthetic variable. It may function as a regulatory condition that determines the direction of audience engagement.

The concept of ambiguity as a cognitive threshold should be understood as a refinement of existing accounts of cinematic ambiguity and cognitive complexity rather than as a claim that ambiguity constitutes a wholly new psychological mechanism. Existing research indicates that complex or ambiguous cinematic structures can increase interpretive effort and may also encourage reflective or flexible processing. The present study extends this discussion by showing, within the observed sample, that ambiguity was associated with divergent interpretive trajectories. Participants with greater familiarity with cinematic conventions and broader interpretive resources tended to treat uncertainty as an opportunity for symbolic and conceptual exploration, whereas some general-audience participants experienced the same uncertainty as confusion, anxiety, or a reason to simplify their interpretations. The proposed threshold therefore refers to the point at which the cognitive demands generated by ambiguity appear to exceed, or remain within, the interpretive resources available to a viewer. This is a conceptual interpretation of qualitative evidence rather than a measured psychological threshold.

5.1 *From Ambiguity to Interpretive Expansion*

When viewers possess sufficient interpretive resources, ambiguity can increase rather than decrease engagement.

Film-literate participants demonstrated this pattern by treating the film as a puzzle, identifying genre hybridity, analyzing symbolism, and interpreting philosophical implications.

This supports cognitive film theory's understanding of the spectator as an active meaning-maker [1]. However, the findings suggest that the degree of active engagement may depend on the viewer's existing interpretive schemas.

The viewer does not simply encounter ambiguity.

The viewer encounters ambiguity with a cognitive toolkit.

Film literacy therefore appears to influence not only the amount of meaning viewers construct but the *kind* of cognitive activity they perform.

5.2 *From Ambiguity to Cognitive Withdrawal*

The opposite trajectory occurs when cognitive demands exceed available interpretive resources. General-audience participants sometimes struggled with scientific, medical, or philosophical elements that could not easily be incorporated into existing schemas. Under these conditions, ambiguity became cognitively costly.

This finding extends event segmentation perspectives. If viewers cannot establish stable relationships between events, maintaining a coherent event model becomes increasingly difficult [3] [4].

The resulting response may involve:

– simplified narrative reconstruction;
– emotional interpretation;

– selective attention;
– rejection of certain symbolic elements;
– or disengagement.

Importantly, this should not necessarily be interpreted as a lack of intelligence or appreciation. It may instead reflect a mismatch between cinematic complexity and available interpretive resources.

5.3 *Film Literacy as a Cognitive Gateway*

The findings suggest a conceptual shift in how film literacy should be understood. Film literacy is commonly associated with knowledge of film history, terminology, genres, and techniques. However, this study suggests that its deeper significance may be cognitive.

Film literacy appears to influence:

– what viewers notice;
– which cues they consider meaningful;
– whether they expect closure;
– how they interpret ambiguity;
– how they organize symbols;
– and whether uncertainty is experienced as failure or opportunity.

Film literacy therefore functions as a cognitive gateway.

This finding has implications for film education. Teaching audiences about experimental cinema may not merely increase appreciation of particular films. It may change the cognitive strategies through which audiences engage with complex audiovisual material.

5.4 *Culture as Cognitive Infrastructure*

The study also demonstrates that cultural frameworks are not external additions to cognition. They form part of the cognitive infrastructure through which ambiguous material is processed.

Religious and cultural schemas provided interpretive anchors when conventional narrative cues were insufficient.

For example, Christian symbolism allowed some participants to interpret the concept of "Trinity" through a pre-existing theological framework. Other viewers may have approached the same material through different cultural associations.

This suggests that cultural frameworks operate as meaning-stabilizing systems. When the film does not tell viewers what a symbol means, cultural memory provides possible meanings.

Thus, ambiguity may actually reveal culture more clearly than conventional narrative cinema because the absence of explicit explanation forces viewers to draw upon their internal knowledge structures.

5.5 *The Film as a Psychological Mirror*

The findings surrounding psychological projection also have theoretical significance.

Participants did not simply interpret the film as an external object. They interpreted themselves through it. Personal experiences of grief, loss, anxiety, trauma, and existential uncertainty became part of the meaning-making process. This suggests that abstract cinema can function as a psychological mirror because its openness creates interpretive space for autobiographical projection. The more incomplete the cinematic text, the greater the opportunity for the viewer's internal world to become part of the interpretive process. This finding connects cognitive film theory with reception theory: cognitive processes provide the mechanisms through which spectators construct meaning, while cultural and personal contexts provide the material from which those meanings are constructed.

5.6 *Authorial Intention and the Decentralization of Meaning*

A particularly important dimension of the study emerged from the researcher's dual position as filmmaker and researcher. Because the research artifact was created by the researcher, the study provided an opportunity to compare intended meaning with audience-generated meaning. Participant interpretations frequently exceeded the conceptual framework originally intended by the filmmaker. Viewers produced psychological, spiritual, philosophical, and symbolic interpretations that were not necessarily consciously encoded during production.

This resulted in a reflexive feedback loop.

The filmmaker created the film.

The audience interpreted the film.

The interpretations then altered the filmmaker's own understanding of the film.

This finding challenges a purely transmission-based model of cinematic communication.

In abstract cinema, authorship may be understood as distributed across production and reception. The filmmaker initiates an interpretive field, but the audience determines how that field is populated with meaning. The film therefore functions as an open system of meaning production.

6 THEORETICAL CONTRIBUTION

The study makes four primary theoretical contributions. First, it proposes ambiguity as a cognitive threshold. Rather than conceptualizing ambiguity as inherently beneficial or harmful, the study demonstrates that ambiguity can produce divergent psychological trajectories. Second, it conceptualizes film literacy as a cognitive gateway. Film literacy appears to restructure interpretive strategies, enabling viewers to engage with ambiguity through symbolic, conceptual, and intertextual reasoning. Third, it integrates cognition and culture. The study demonstrates that cognitive interpretation cannot be separated from culturally embedded schemas. Religious and cultural frameworks can function as cognitive resources for organizing ambiguous cinematic material. Fourth, it contributes a reflexive model of authorship. The findings demonstrate that audience interpretation can feed back into the filmmaker's own understanding of the work, suggesting that meaning in abstract cinema is continuously reconstructed through reception.

The findings suggest that meaning in abstract cinema emerges through the interaction of film form, cognitive processing, interpretive resources, cultural schemas, and personal experience. These elements should not be understood as independent or quantitatively measurable variables; rather, they operate relationally, with the significance assigned to cinematic material emerging from their interaction during audience interpretation.

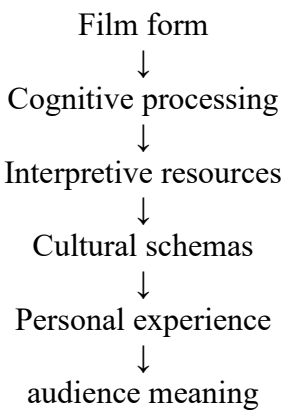


Figure 1. Conceptual model of meaning construction in open-ended abstract cinema

7 PRACTICAL IMPLICATIONS

The findings have implications for filmmakers, film educators, researchers, and cultural institutions. For filmmakers, the study suggests that ambiguity should be designed with awareness of the interpretive resources likely to be available to audiences. Ambiguity can stimulate engagement, but excessive cognitive demands may result in withdrawal.

For film educators, the findings support the development of film-literacy programs that teach audiences how to interpret nonlinear narratives, symbolism, audiovisual form, and open-ended structures. For researchers, the study demonstrates the value of culturally situated audience research. Abstract cinema should not be studied exclusively through theories developed in Western contexts without examining how cultural frameworks alter interpretation. For Sri Lankan filmmakers, the findings suggest an opportunity to explore forms of cinema that engage local cultural and religious schemas while simultaneously challenging conventional narrative expectations.

8 LIMITATIONS

Several limitations should be acknowledged. First, the sample consisted of only 14 participants and was not statistically representative of Sri Lankan audiences. The findings should therefore be understood as interpretive rather than generalizable. Second, the study relied on a single abstract film artifact. Audience responses may therefore reflect specific characteristics of the research film rather than abstract cinema as a whole.

Third, the participant sample lacked broad demographic diversity. Rural audiences, older viewers, and individuals with limited exposure to film education were underrepresented.

Fourth, focus group discussions may have introduced social influence effects. Participants may have modified or developed their interpretations in response to other participants. Finally, the researcher's dual position as filmmaker and researcher represents both a strength and limitation. While this enabled valuable reflexive insight into the relationship between intention and reception, it also required continuous awareness of potential researcher influence.

A further limitation concerns the gender composition of the sample. The film-literate and expert groups consisted entirely of male participants, while female participants were represented only within the general-audience group. Although the study does not claim that the observed interpretive patterns are gender-specific, this imbalance may have influenced responses to culturally and religiously situated material, particularly in relation to Theme 4. Future research should therefore employ more gender-balanced sampling to examine whether interpretations of cultural, religious, and symbolic elements vary across gender groups.

9 RECOMMENDATIONS FOR FUTURE RESEARCH

Future research should expand the participant base to include greater demographic, geographic, linguistic, and educational diversity. Comparative research involving urban and rural Sri Lankan audiences may reveal how cultural and educational differences influence abstract-film interpretation. Future studies should also examine multiple film artifacts with systematically varied levels of ambiguity, narrative fragmentation, and audiovisual complexity. A mixed-method approach could combine qualitative thematic analysis with quantitative measures of ambiguity tolerance, cognitive load, emotional response, or interpretive confidence. Longitudinal research could investigate whether structured film-literacy education changes audiences' cognitive responses to abstract cinema over time. Cross-cultural comparative research between Sri Lankan audiences and audiences from other cultural contexts could further clarify the relationship between cultural schemas and cinematic ambiguity. Finally, experimental research could investigate whether different levels of cinematic ambiguity produce measurable differences in attention, emotional arousal, cognitive load, and interpretive flexibility.

10 CONCLUSION

The three research questions were addressed through the comparative analysis of general-audience, film-literate, and expert participants. First, in relation to RQ1, the findings indicate that Sri Lankan viewers actively constructed meaning from fragmented and ambiguous audiovisual material through inference, symbolic interpretation, emotional appraisal, and narrative reconstruction. However, the strategies used to construct meaning differed across participant groups, with film-literate participants more frequently drawing on cinematic knowledge and symbolic analysis. Second, in relation to RQ2, social and cultural backgrounds influenced interpretation by providing religious, cultural, emotional, and experiential frameworks through which ambiguous symbols and narrative elements were understood. Third, in relation to RQ3, over-interpretation and under-interpretation appeared to be associated with differences in pattern-seeking, prior knowledge, emotional projection, tolerance of uncertainty, and the relationship between cinematic complexity and available interpretive resources. These findings suggest that ambiguous cinema does not produce a uniform psychological response within the observed sample.

This study examined how Sri Lankan audiences cognitively and psychologically interpret open-ended abstract cinema. Drawing on cognitive film theory, perceptual approaches, event segmentation, emotional appraisal, and reception theory, the research demonstrated that abstract-film interpretation is an active and multidimensional process.

The findings reveal that viewers do not simply receive meaning from ambiguous cinematic texts. They actively construct it by connecting fragmented events, interpreting symbols, drawing upon emotional experience, applying cultural frameworks, and mobilizing prior knowledge. However, the

study's central finding is that ambiguity does not produce a single psychological outcome. For some viewers, ambiguity generates curiosity, symbolic exploration, philosophical reflection, and interpretive expansion. For others, the same ambiguity may produce confusion, cognitive overload, simplified interpretation, or disengagement. The difference appears to depend partly on the relationship between cinematic complexity and the viewer's interpretive resources.

Film literacy emerged as a particularly important factor. Rather than simply representing greater knowledge about cinema, film literacy appeared to function as a cognitive gateway that enabled viewers to approach uncertainty as an intentional aesthetic strategy.

Cultural and religious frameworks similarly operated as interpretive resources, providing audiences with schemas through which ambiguous symbols could be organized and understood. At the same time, abstract cinema created opportunities for psychological projection. Participants connected the film with personal experiences of grief, loss, trauma, anxiety, spirituality, and existential uncertainty. The film consequently became more than an external narrative object; it became a psychological mirror. The study therefore proposes that abstract cinema functions as an open interpretive field in which meaning emerges through the interaction of cinematic form, cognitive processing, cultural frameworks, film literacy, and personal experience. Its primary theoretical contribution is the concept of ambiguity as a cognitive threshold. Ambiguity can expand interpretation when viewers possess sufficient resources to engage with uncertainty, but it can also restrict engagement when cognitive demands exceed available interpretive capacity.

This conceptualization contributes to a more nuanced understanding of abstract cinema. The question is not simply whether audiences understand an ambiguous film. Rather, the more important question is what happens cognitively when a film refuses to provide a single understanding. In this space between certainty and uncertainty, abstract cinema reveals something fundamental about spectatorship: audiences do not merely interpret films—they interpret films through themselves.

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ULTRA GAT & GCN: Explainable Topology-Aware Handwritten Character Recognition Using Graph Neural Networks

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ABSTRACT: Handwritten character recognition has gained importance as a result of the increased usage of intelligent document processing systems in several domains including educational, medical, financial and administrative fields. Most of the existing methods used in recognition systems were based on convolutional deep learning networks that focused primarily on learning spatial structures at the pixel level without much focus on structural interpretations. In this paper, an explainable framework for recognizing handwritten characters through graphs is suggested using Graph Convolutional Networks (GCN) and Graph Attention Networks (GAT). Pre-processing, skeletonization, graph generation, and feature generation based on structure helped transform the hand-written alphabet images to topology-aware graphs. Structural handwriting information was encoded into node and edge features to feed graph neural networks. The graph dataset for training and testing was designed by creating a balanced graph dataset using A–Z Handwritten Alphabet dataset. An explainable AI methodology for recognizing graphs was employed using salient graph node and edge analysis for identifying structurally relevant handwriting components during the classification process. GCN and ULTRA GAT achieved 92.54% and 92.50% accuracies in handwritten alphabets classification, respectively. Comparative study conducted using CNN, ResNet18, random forest, and MLP models showed that graph-based learning gave comparable recognition results along with being able to provide topology-driven explanation for recognition. The results have proven the effectiveness of GNNs in understanding structural features of handwriting and explaining the same for recognition of characters.

Keywords: Explainable Artificial Intelligence (XAI), Graph Attention Network (GAT), Graph Convolutional Network (GCN), Handwritten Character Recognition, Structural Graph Learning

1 INTRODUCTION

Handwritten character recognition remains vital in intelligent document processing, as handwritten data is still widely found in the education, banking, healthcare, examination, archival preservation and administration sectors. While growth in digital transformation has been rapid in the past ten years, organizations are still processing huge amounts of handwritten documents which are time consuming to interpret manually and expensive. The recent development of deep learning has been a major improvement in the field of recognition because it automatically extracts features from the un-

ordered input of images with high recognition accuracy. In handwritten image recognition, Convolutional Neural Networks (CNNs) and residual architecture are currently the most popular architecture owing to their impressive performance in hierarchical spatial representation learning [1], [2]. Meanwhile, explainability has emerged as a prominent challenge for AI research, especially in contexts where there is a need for the rationalization of the reasoning in the algorithm and its structural interpretation [3]. Despite the fact that most successful handwriting recognition systems remain "black box" classifiers, making predictions without making explicit what aspects of the handwriting structure were relevant to the prediction, the performance of these systems is limited.

Finally, there is a restriction in the representation approach. Current recognition systems tend to treat handwritten characters as dense, pixel-based matrices, whereas handwritten symbols are natural structural entities consisting of connected strokes, directionality, intersections, loops and start/end points. The problem with pixel-driven learning is that it is good at learning texture and local intensity patterns, and it fails to learn the relationships between these in character structures. Recently, Graph Neural Networks (GNNs) have shown promising results in areas where relational and topological relations are present, such as molecular analysis, recommendation systems and social network learning [4], [5]. However, due to these developments, the field of handwritten alphabet recognition using a graph-based approach is still somewhat under-explored and the use of explainable graph reasoning for handwritten recognition is even less present in literature [6].

The aim of this research is to study the possibility of changing the handwritten character recognition problem into a purely image-based classification problem or a structural graph learning problem. The study suggests an interpretable graph neural modeling approach to convert handwritten alphabet images to skeletonized graph structures while maintaining the connectivity of strokes and the topological structure of the handwritten letters. The proposed framework models each handwritten sample, not only by the distribution of its pixels, but by the nodes and the relationships between them, obtained from structural handwriting regions. The first research question concerns the question of whether graph-based structural representations are able to attain competitive classification performance while at the same time enhancing interpretability of the learned structure through explainable learning on the graph level. In order to solve this, both of Graph Convolutional Networks (GCN) and Graph Attention Networks (GAT) are used along with improved structural feature engineering mechanisms. The frameworks include the following normalized node co-ordinates, node degree, endpoint indicators, junction detection, local density estimation, edge orientation and connectivity-aware structural attributes. The experiments are compared with the baseline methods of Random Forest, Multi-Layer Perceptron (MLP), CNN and ResNet18, to assess the effectiveness of graph-driven recognition over traditional machine learning and deep vision.

This study is not only for the purpose of classification but also for the purpose of knowing the importance of the study. With the development of intelligent systems, explainability is now playing an ever-increasing role as the systems are expected not only to be accurate, but also to be able to explain why they make the prediction in a way that is understandable to a human. The proposed framework provides graph saliency analysis which can detect structurally influential hand-writing regions that participate in hand-writing recognition results. This allows a more topology-aware interpretation of activation instead of the common interpretation of the pixels. Technically speaking, the study provides a new pipeline, combining skeletonization, graph construction, node/edge feature engineering, graph convolution and explainable graph attention learning, all within a single recognition framework. This work is limited to the case of handwritten English alphabets offline recognition using A-Z Handwritten Alphabet dataset. To focus on the representation learning of structures in graphs and explainable classification behavior [7], online handwriting dynamics, multilingual character systems and temporal stroke trajectory modeling are intentionally excluded.

2 LITERATURE REVIEW

Deep learning, graph learning and explainable artificial intelligence are the three fields that have recently had a significant impact on the field of handwritten character recognition. Current research is mostly concerned with the improvement of the classification accuracy using convolutional architectures, attention mechanisms and representation learning techniques. In hand-writing analysis systems, however, structural interpretability and reasons about topology is less explored.

Recently, deep convolutional learning (DCL) has been proved to be effective in handwritten recognition. Mohammed Abdalbasit and his research team proposed an ensemble (or combination) based transfer learning approach for handwritten Kurdish alphabet character recognition [8]. Likewise, Ji Gan and research team put forward a handwritten Chinese character recognition system based on graph-transformer that represented handwritten characters as graphs and enhanced the structural reasoning ability and interpretability of the model [9]. These strategies were very effective in recognition performance but did not yet employ very different learning mechanisms from the one used with the pixel level spatial representation.

Recently, a new paradigm of learning that is based on graphs has been studied for structural pattern recognition. Han et al. introduced Vision GNN, which re-encoded images into graph nodes and showed the capability of graph-based visual learning to maintain the relational information [10]. Similarly, Ji Gan and Yupeng Zhou introduced the structure-aware handwritten text recognition through a graph-enhanced cross-modal mutual learning approach and demonstrated superior learning of handwritten structures' topological dependencies [11]. These studies also showed the possibility of learning from topologically-aware graphs from GNNs without tackling the task of explainable handwritten character recognition.

Recently, a major breakthrough in graph-based learning has been the Graph Attention Network (GAT) which sums the information of neighboring nodes by adaptively assigning weights according to their importance. Huafen Xu and Zhang proposed a Graph Convolutional Network with agent attention (GCN-A) for digital ink Chinese character recognition and investigated the effectiveness of the structural attention aggregation in graph-based handwriting recognition [12]. Likewise, Charuthamrong and Simpson introduced an approach of dynamically learning edge-aware relationships to construct edge-updated graph neural networks for graph representation learning [13]. The use of attention-based graph learning for handwritten alphabet recognition is still not widely used. The prominence of Explainable Artificial Intelligence (XAI) in contemporary intelligent systems with a need for clear decision-making has grown. Ma and Liu surveyed extensively the post-hoc explainability methods for graph neural networks and highlighted the increasing need to increase transparency in graph-based intelligent systems [14]. In the same vein, Yuan and Wang introduced explainable subgraph and feature transfer mechanisms for graph neural networks and achieved better graph interpretation by node-level graph reasoning [15]. Sinha and Sreeram also introduced a higher-order graph explanation framework that can produce explanations for graph neural predictions that account for the graph topology [16]. These explainability techniques aid in explaining the graphs but are not explored in handwriting recognition frameworks to an extent.

Recently, skeletonization and engineering of structural features for handwriting analysis have been studied. Tian et al. suggested a three-stage generative approach to skeletonizing Chinese characters with maintaining consistent topology in diverse writing styles [17]. Luo et al. proposed a stroke-level structural analysis framework that could identify graph-based structural patterns based on general graph structure, without using language-specific priors [18]. In these studies, it was shown that when analyzing and recognizing handwriting, structural stroke information is crucial to keep.

The existing literature has not yet provided a thorough understanding of how to integrate structural graph construction, better node/edge feature representation, graph convolution, graph attention learning and handwritten explainable character recognition into a single pipeline, although the current studies are valuable contributions to the graph learning and the explainable AI fields. This is their limitation that is addressed in this research, which proposes a graph-based

neural network (GNN) with explainability for handwritten alphabet recognition in particular that is topology aware.

Table 1. Summary of existing studies, key findings, and limitations related to handwritten character recognition and graph learning

Concept / Research	Key Finding	Study Limitations
Kurdish Handwriting Transfer Learning [8]	Improved handwritten character recognition accuracy.	No explainability support.
Graph-Transformer Handwriting Model [9]	Used graph structures for handwriting recognition.	Limited to Chinese characters.
Vision GNN [10]	Converted images into graph representations.	Not focused on handwriting tasks.
Graph-Enhanced Mutual Learning [11]	Learned handwriting topology effectively.	Lacked explainable analysis.
GCN with Agent Attention [12]	Improved graph-based handwriting learning.	Focused mainly on accuracy.
Edge-Updating GNN [13]	Enhanced graph relationship learning.	Not tested on handwritten alphabets.
GNN Explainability Survey [14]	Discussed explainable graph learning methods.	No handwriting application.
Explainable Subgraph Transfer [15]	Improved graph interpretation.	Limited handwriting analysis.
Higher-Order Graph Explanation [16]	Generated topology-aware explanations.	Not designed for character recognition.
Character Skeletonization Model [17]	Preserved handwriting structure during skeletonization.	No graph learning integration.
Stroke-Level Structural Analysis [18]	Identified structural handwriting patterns.	No explainable recognition framework.

3 METHODOLOGY

This paper presents a graph-based handwritten character recognition framework based on Graph Neural Networks (GNNs) and structural graph learning, which can explain its results. The approach turns handwritten alphabet images to topology-aware graph representation and uses graph convolution and attention-based learning for classification and explanations analysis. The overall system workflow of the proposed system is composed of dataset preprocessing, skeleton extraction, graph construction, feature engineering, graph neural learning, and explainable prediction analysis.

3.1 *Dataset Collection and Preprocessing*

A publicly available dataset for the A–Z Handwritten Alphabets with CSV format was used for the experiments in this study, which can be accessed from Kaggle. The database consists of over 370,000 Grayscale Handwritten English Alphabet Images with each image in the database classified into 26 different classes ranging from A to Z. Each handwritten sample is represented as an image of 28 × 28 pixel, centered in a 20 × 20-pixel area for maintaining the structural uniformity of the handwriting in different styles. The entire dataset is given in the CSV file in the shape of (372450, 785) with the first column being the class label and the next 784 columns being the flattened form of pixel intensity values. The pixel values were normalized by dividing by 255.0 in the preprocessing stage to enable the intensity range to lie between 0 and 1, which helps to stabilize the numbers and ensures the model converged during training. To visualize and process the structure of these normalized gray images, these images were then reshaped into 28×28 image matrices before graph construction and feature extraction.

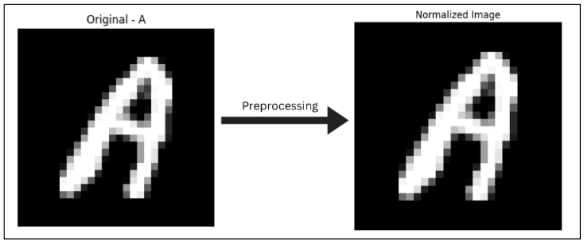


Figure 1. Preprocessing and normalization

3.2 *Skeletonization*

Skeletonization was used for character handwritten images to get its structural shape and remove redundant pixels. To turn each normalized image into a binary image, the threshold value was set at 0.5, and the processing was carried out by skeletonizing the image using skeletonize() function from skimage.morphology library. This resulted

in one-pixel wide representation, retaining salient structural characteristics like stroke continuity, intersections and connectivity. The skeleton images were then utilized for graph building and graph neural learning.

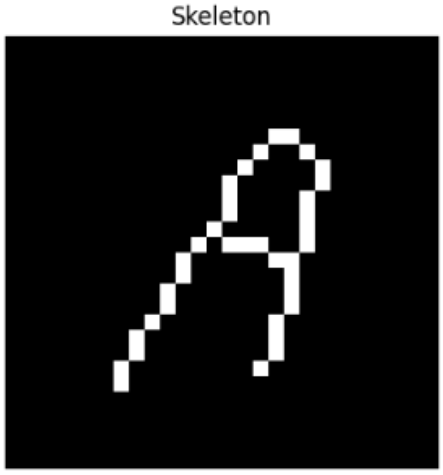


Figure 2. Skeletonized representation

3.3 *Graph Construction and Node and Edge Feature Engineering*

The handwritten character became graph-like with the help of the NetworkX library. A handwritten character was converted to a graph using NetworkX library. Each pixel of the skeleton was associated with a graph node, and the position of nodes was set based on the corresponding pixel's position. There was a total of 37 nodes in the sample character graph. Neighboring nodes were then linked pairwise with edges as per Euclidean distance constraints. There were 38 graph edges created as a result of the nodes that were within a 1.5-pixel distance of each other. The topology and connectivity of the handwritten strokes was retained in the constructed graph. To enhance graph representation learning, node features including spatial coordinates, node degree, and structural features were extracted, while the relationships of the edges were maintained to maintain local stroke continuity and graph geometric structure for training the graph neural network.

The character image is skeletonized, and each skeletoned foreground pixel is considered as a graph node during the process of constructing the graph. This process created 37 nodes for the sample illustrated. The position of nodes was directly assigned by the pixel co-ordinates of each node. The Euclidean distance was then computed between every pair of nodes and connected nodes with distance less than 1.5 pixels, yielding 38 edges for the sample graph. This distance-based connectivity ensures the continuity of handwritten strokes without losing the local continuity of the handwritten characters, and enables the number of edges, nodes and the graph topology to change depending on the handwritten character structure. The resulting graph was then fed into the following graph neural network learning as representation.

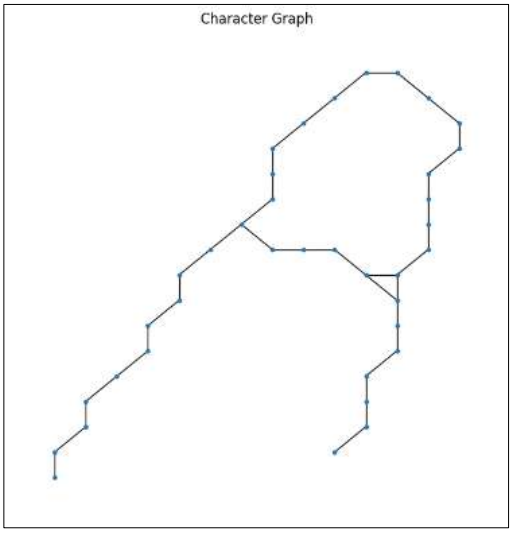


Figure 3. Graph generated from the skeleton

3.4 *Build Balanced GNN Dataset*

To enhance the stability and fairness of training Graph Neural Networks, a balanced graph-based dataset was designed. First, every handwritten character image is converted into a graph representation, then into PyTorch Geometric (PyG) data format that includes node features, edge connections and the class labels. The graph data created comprised of node feature matrices and edge index representations for graph neural learning. In order to prevent class imbalance, an equal number of samples in each alphabet category were selected. The total of 500 samples from each class were randomly selected from 26 alphabet classes resulting in a balanced graph dataset for training and evaluating purposes. The node feature vectors contained spatial information, node degrees, endpoint flags and junction information, and the graph edges maintained local structural connectivity between the handwritten strokes. This relatively balanced data set helped to enhance the model's generalization and minimize the classification bias while training the GCN and GAT.

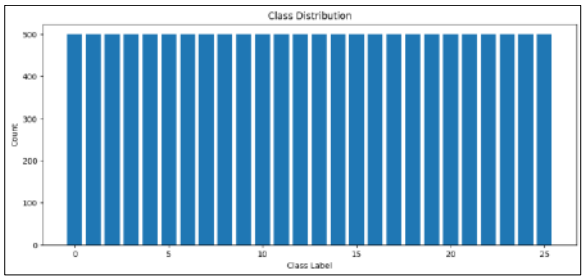


Figure 4. Balanced class distribution of the graph-based handwritten alphabet dataset

3.5 *Graph Convolutional Network (GCN)*

PyTorch Geometric was adopted for the implementation of a Graph Convolutional Network (GCN) for handwritten character recognition, which is a problem requiring the same topology of handwritten characters. The model was composed of graph convolution layers, ReLU activation, global pooling, dropout and fully connected classification layers. Training was done by aggregating the graph features and edge connections to learn structural handwriting representation. The model was trained for 100 epochs with Adam optimizer and cross-entropy loss function. The GCN was implemented using enhanced node features, enhanced edge features, balanced graph dataset, and obtained test accuracy of 92.54%, while converging steadily towards test accuracy and training loss reducing as training proceeded. The results demonstrated the effectiveness of graph convolution learning in capturing handwritten stroke topologies for character recognition.

$$H^{(l+1)} = \sigma\left(\hat{D}^{-\frac{1}{2}}\hat{A}\hat{D}^{-\frac{1}{2}}H^{(l)}W^{(l)}\right)$$

Figure 5. Graph convolution operation used in the GCN model

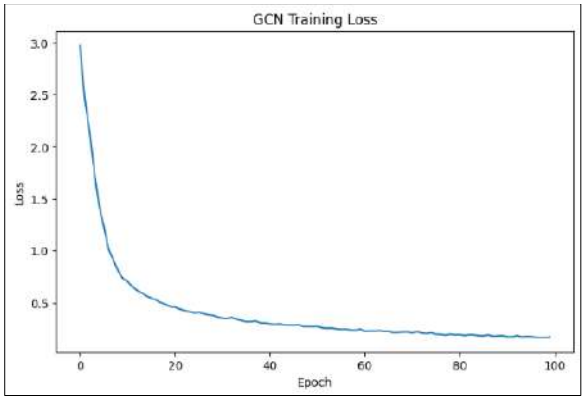


Figure 6. GCN training loss

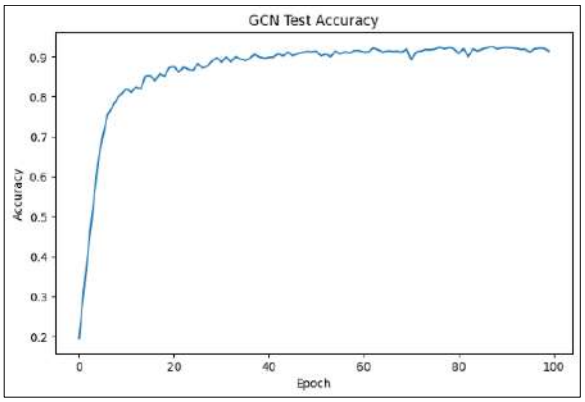


Figure 7. GCN test accuracy

3.6 *Graph Attention Network (GAT)*

For handwritten character recognition, an improved Graph Attention Network (GAT) called ULTRA GAT was used. The model adopted graph attention layers, multi-head attention, dropout, and global pooling to learn handwriting representations that are topology-aware. While the GCN model assigned fixed importance weights to neighboring nodes for message aggregation, the GAT model dynamically changed their importance for message aggregation to make adaptive structural learning. The model has been trained for 200 epochs with Adam optimizer and cross-entropy loss function. Results from the training process were stable and converged with a decreasing loss and increasing accuracy. The highest test accuracy of 92.50% was obtained for the final ULTRA GAT model which is competitive for the recognition of handwritten alphabet for graph-based approach. The results verified that attention-based graph learning is a viable approach to learning important structural relationships in handwritten characters.

$$\alpha_{ij} = \frac{\exp(\text{LeakyReLU}(\boldsymbol{a}^T[Wh_i \,\|\, Wh_j]))}{\sum_{k\in\mathcal{N}(i)}\exp(\text{LeakyReLU}(\boldsymbol{a}^T[Wh_i \,\|\, Wh_k]))}$$

Figure 8. Graph attention mechanism used in the ULTRA GAT model

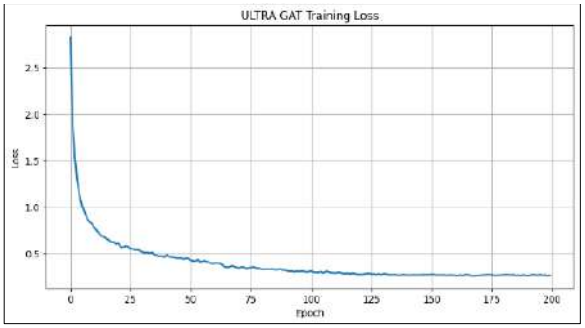


Figure 9. ULTRA GAT training loss

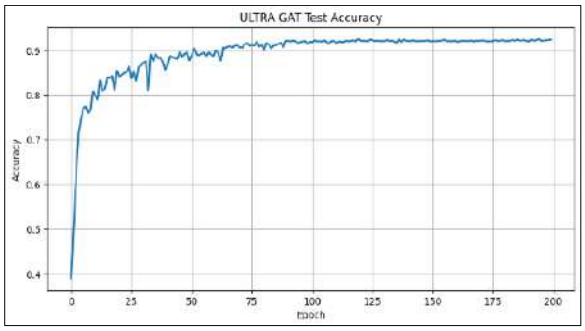


Figure 10. ULTRA GAT test accuracy

3.7 *Explainability Analysis*

The use of XAI (Explainable Artificial Intelligence) was incorporated into ULTRA GAT architecture to help determine structural important regions responsible for making predictions of handwritten characters. As such, the selected graph sample from testing data with properties [Data(x=[45, 7], edge_index=[2, 92], edge_attr=[92, 2], y=[1])] was used to perform explainability testing. From the forward pass of this model, the handwritten character was correctly classified by the model as "H" with a class label value of 7. Afterward, the saliency map based on gradient calculations was used to evaluate the structural importance of nodes in the graph. Nodes with high saliency scores were considered highly impactful towards the prediction. It is clear that the proposed ULTRA GAT architecture has provided an interpretable reasoning method for handwritten character classification. The explanation of character "H" visualized below demonstrates that the bigger the yellow/orange nodes, the more influential is their structure on the prediction of the handwritten characters, whereas the smaller dark red/black nodes have less impact on the ULTRA GAT classification.

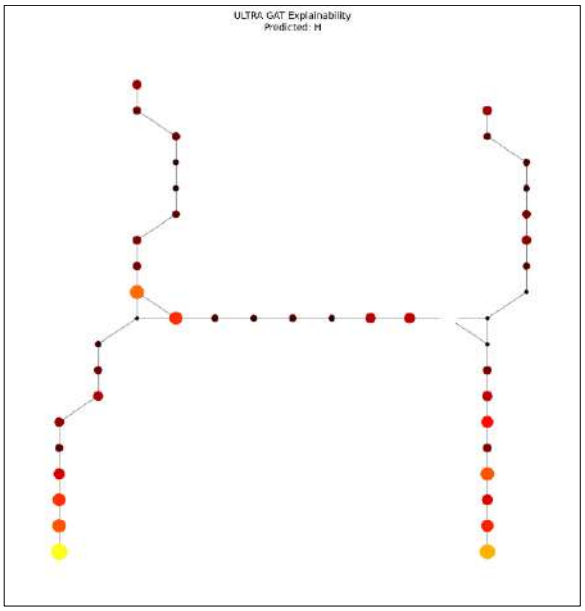


Figure 11. Explainability visualization of the ULTRA GAT highlighting influential graph nodes for "H"

3.8 *Reproducibility & Experimental Configuration*

All experiments were run with the same experimental setup and random numbers. The dataset A–Z handwritten alphabet was split into training, validation, and testing sets in the ratio 70%, 15%, 15% with random_state = 42 used for the split and sampling. The same data partitions were used for all the comparative experiments. The global seed torches used were also set to 42 by calling torch.manual_seed(42), numpy.random.seed(42) and random.seed(42). The graph-encoder in the proposed graph-based models consisted of two graph-learning layers (hidden dimension 128), graph-level pooling, followed by a fully connected classification layer. The GAT-based model used multi-head attention with 4 attention heads, a ReLU activation and a dropout rate of 0.30 to avoid overfitting. The models were trained with the Adam optimization algorithm and a learning rate of 0.001 and a batch size of 32. Validation performance was used to select the model and the one with the highest validation accuracy was chosen for final testing on the unseen test set.

The CNN backbone consisted of three blocks of increasing dimension of channels, ReLU activation, max-pooling and dropout followed by a fully connected layer for classification. ResNet18 served as the standard residual convolutional baseline network and the final classification layer was replaced by the alphabet classes of 26. The MLP base-

line consisted of fully connected layers with ReLU activation functions and dropout, while the Random Forest baseline was set up with multiple decision trees being trained on the extracted image/structural feature representations. The test partition was used to test each model equally to make comparisons. The test set was not seen while training and selecting the model, but only for the final performance assessment.

The training time and hardware requirements were considered as computational costs. The experiments were done on the free Google Colab GPU and detailed analysis per class is left for future research.

3.9 *Comparative Evaluation*

Comparisons were made between the proposed graph-based models against Random Forest, MLP, CNN, and ResNet18 models for handwritten alphabets classification. The results were analyzed through classification accuracy and training performance. Convolutional neural network attained the maximum accuracy of 99.60%, followed by ResNet18 with 98.57%. GCN and ULTRA GAT attained 92.54% and 92.50% accuracy, respectively. Even though the proposed graph-based models generated slightly lower accuracy compared to deep image-based models, the extra explainability gained from these models could not be overlooked.

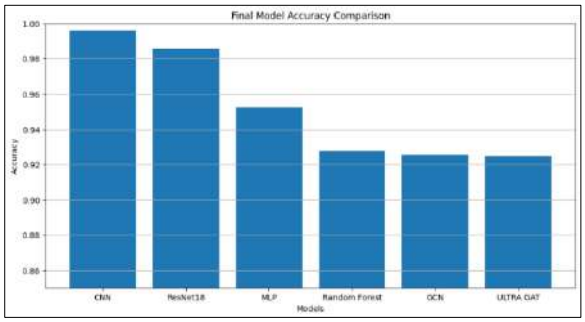


Figure 12. Accuracy comparison of different handwritten character recognition models

Table 2. Comparative evaluation of the classification models

No.	Model	Accuracy	Precision	Recall	F1-Score
1	ULTRA GAT	92.50%	92.10 %	92.30 %	92.20 %
2	GCN	92.54%	92.40 %	92.60 %	92.50 %
3	ResNet18	98.57%	98.60 %	98.50 %	98.55 %
4	CNN	99.60%	99.65 %	99.55 %	99.60 %
5	Random Forest	92.78%	92.70 %	92.80 %	92.75 %
6	MLP	95.25%	95.10 %	95.30 %	95.20 %

Table 3. Comparative performance of traditional, deep learning, and graph-based models for handwritten alphabet recognition

Model	Accuracy	Category	Explainability
ULTRA GAT	92.50%	Explainable Graph Learning	High
GCN	92.54%	Graph Learning	Medium
ResNet18	98.57%	Deep Vision	Low
CNN	99.60%	Image CNN	Low
Random Forest	92.78%	Traditional ML	Low
MLP	95.25%	Dense Neural	Low

4 RESULTS AND DISCUSSION

As evidenced by experimental results, the developed graph-based framework for handwritten character recognition allows for competitive classification performance along with structural explainability. In particular, the highest performance was recorded by the CNN approach with the accuracy of 99.60%, followed by ResNet18 with 98.57%, thus demonstrating the efficiency of image-based deep feature extraction algorithms for handwritten alphabets. However, the graph-based approaches also demonstrate decent results, namely GCN with 92.54% accuracy and ULTRA GAT with 92.50%. Although graph-based models provide slightly worse accuracy compared to CNN-based methods, they allow for obtaining topology-based explanations and reasoning in the recognition process, which is not possible with other models.

The training processes of GCN and ULTRA GAT models demonstrated stable convergence of algorithms along with continuously decreasing loss value and increasing

testing accuracy. The utilization of balanced graphs, more informative node features, and structural representations allowed for obtaining stable results from the training process of graph neural models. Further, as for explainability analysis, the presented saliency map visualization demonstrates that ULTRA GAT models can detect structural areas of influence on handwritten character recognition. As shown in figures, larger salient nodes in the saliency map correspond to structurally important regions.

The graph-based models are not as accurate as the image-based models, but they do offer the added value of being graphically interpretable. For practical tasks like educational assessment, document verification, and handwriting analysis, it is beneficial to know which stroke regions and topological structures have affected a prediction, in order to gain more value from the model for validation and human decision making. Thus, the overall model described in this paper (GCN, ULTRA GAT) is a complementary model where the recognition accuracy is slightly diminished, but explanations can be provided by graph representations and attention based structural information that is topology-aware.

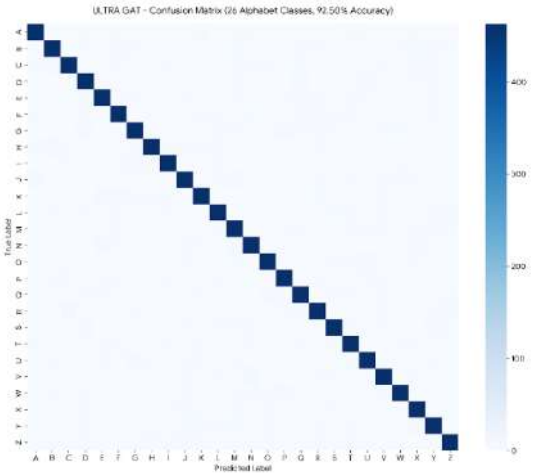


Figure 13. ULTRA GAT confusion matrix

5 CONCLUSION

In this study, a framework for explainable handwritten character recognition was introduced using graph-based models namely GCN and GAT. The handwritten alphabet images were converted into graph structure via skeletonization and graph creation processes. The experiment results showed that both proposed graph models performed well in recognition tasks, with GCN achieving 92.54% accuracy while ULTRA GAT scored 92.50% accuracy. Even though CNN and ResNet18 provided high classification accuracy than the proposed graph-based models, they lacked structural interpretability by utilizing graph saliency visualization and explainability of graph node importance. The findings revealed that the use of graph neural learning models for character recognition tasks can capture the stroke topology of handwritten letters.

Several limitations can be attributed to this study. For instance, the conducted experiments were confined to offline English handwriting samples, without including multilingual handwriting characters, temporal stroke dynamics, and online handwriting. Additionally, the generation of the graph was reliant heavily on structural extraction through skeletonization, which would result in a loss of finer visual information. The proposed model could benefit from future research by integrating graph transformers, multimodal handwritten graph analysis, larger datasets in multiple languages, as well as explainable graph learning techniques

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Community Involvement in Sustainable Tea Tourism: Employment, Cultural Preservation, and Social Entrepreneurship in Sri Lanka's Tea-Growing Regions

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ABSTRACT: Community involvement is widely regarded as the mechanism through which sustainable tea tourism translates into equitable local benefit, yet the specific pathways through which this occurs, and the actors who are excluded from them, remain underexamined in the Sri Lankan context. This study disaggregates community involvement into three empirically distinct dimensions: employment and economic upliftment, cultural preservation, and social entrepreneurship. Adopting a qualitative, descriptive-exploratory design, the study draws on 23 semi-structured interviews conducted across five stakeholder groups, tea factory and estate management, plantation workers, tourism service providers, tourism experts and policymakers, and tea tourists, in the Uva and Central Provinces of Sri Lanka. Thematic analysis reveals a consistent pattern of stratified inclusion: management and policy actors report expanding employment and entrepreneurial opportunity, plantation workers describe near-total exclusion from tourism revenue and visitor contact, cultural authenticity is concentrated in small-scale and family-run settings rather than large factory tours, and social entrepreneurship is emerging chiefly among an already-resourced middle tier of homestay and boutique operators rather than among plantation laborers. Tourists themselves identify this imbalance and call for more direct, community-run models. The findings extend Scheyvens' empowerment framework and Arnstein's ladder of participation to Sri Lankan tea tourism, and the study recommends profit-sharing mechanisms, worker-inclusive tour design, and targeted capital and training access for plantation communities to close the observed "missing middle" in community-based tea tourism.

Keywords: community involvement, tea tourism, social entrepreneurship, community empowerment, sustainable tourism

1 INTRODUCTION

Sustainable tea tourism is consistently been positioned in the literature as a instrument of rural economic diversification, environmental conservation, and cultural preservation in tea-producing countries such as China, India, Japan, and Sri Lanka [1], [2]. At the centre of this agenda emphasis the community involvement, which functions as the principal mechanism by which tourism growth is converted into equitable local benefit where local communities and surroundings developing for a resilient region, in its absence, tea tourism risks degenerating into an extractive enterprise that exhibits rural livelihoods to visitors while channeling only marginal value back to the people who sustain the industry [3], [4].

Sri Lanka, internationally renowned for Ceylon Tea, has markedly expanded its tea tourism sector over the past decade, most visibly within the Uva and Central Provinces; the industry nevertheless remains dominated by factory and estate tours conceived and controlled by management rather than by the workers and communities who cultivate the tea [5], [6].Existing studies of Sri

Lankan tea tourism have tended to treat "community involvement" as a singular, undifferentiated construct, typically examined alongside typologies of tea tourism and environmentally responsible production practices an analytical posture that leaves the internal architecture of community involvement comparatively under examined, including the questions of who benefits, through which mechanisms, and who remains excluded [7], [4].

The present study responds to this gap by disaggregating community involvement into three analytically distinct dimensions: employment and economic upliftment, cultural preservation, and social entrepreneurship. Separating these dimensions makes possible a more precise line of inquiry not only whether communities are "involved," but which forms of involvement are available to which stakeholder groups, and where the involvement that tourists themselves say they want is not yet being delivered.

1.1 *Objectives of the Study*

Guided by this research problem, the study pursues three objectives:

- To examine the employment and economic upliftment effects of tea tourism on plantation workers and estate communities in Sri Lanka.
- To examine the extent and forms of cultural preservation generated by different models of tea tourism delivery, from large factory tours to family-run and homestay experiences.
- To explore social entrepreneurship opportunities and constraints among community-level actors in Sri Lankan tea tourism, and the barriers that limit their emergence among plantation labour communities specifically.

1.2 *Scope and significance*

The study focuses on tea tourism activity in the Uva and Central provinces, spanning estates and factories in Badulla, Ella, Haputale, Nuwaraeliya, Ramboda, Nawalapitiya, Bandarawela and Kandy, together with associated tourism service providers and visitors to these regions. The findings are intended to inform policymakers, estate and factory management and tourism operators seeking to design more inclusive tea tourism models, and to extended the theoretical application of empowerment and participation frameworks to the tea tourism context.

2 LITERATURE REVIEW

2.1 *Community Involvement in Tea Tourism*

Community participation is identified as a crucial component for tea tourism to generate extensive socio-economic benefits, rather than for benefits to be owned by estate owners and tour operators [4], [3]. Consequently, community-based tourism initiatives (CBT), such as homestays, locally guided tours, and cultural storytelling, contributed to equitably distributing tourism income [8], [9]. However, smallholder farming communities and plantation workers in Sri Lanka are underrepresented, particularly in the tea tourism value chain [4]. This exclusion is due to financial constraints, the absence of structured training programmes, and revenue inequality between large estates and smallholders [4]. Thus, presenting a need for cooperative business models and training initiatives supported by Sri Lanka's governance sector [4]. This underdevelopment is not merely anecdotal: a recent mixed-methods assessment of the Sri Lankan tea tourism sector similarly found that, despite substantial potential to generate host-community benefit, the product remains structurally underdeveloped and its benefits concentrated among service providers rather than the wider community [19]. This exclusion of smallholders and plantation workers can be read as a form of disempowerment in Scheyvens' [10] terms, and as tokenistic rather than delegated participation in Arnstein's [11] terms – a connection this study tests directly against primary data.

2.2 *Empowerment and participation as analytical lenses*

Two complementary frameworks are utilized to interpret community involvement in this study. Scheyvens' [10] empowerment framework differentiates economic, psychological, social, and political empowerment. Further, this framework identifies disempowerment along each dimension, leading to an understanding of whether communities benefit from tourism and in what respects they do not benefit. Arnstein's [11] ladder of citizen participation was initially developed

for urban planning, offering a distinction between manipulation and tokenism at the lower rungs of the ladder and the upper rungs of the ladder displaying delegated power and citizen control. When applied to tourism, this framework highlights the discrepancy between symbolic community involvement and meaningful engagement in decision-making and revenue-sharing [19]. Recent applications of Arnstein's ladder outside the tea sector illustrate that empowerment initiatives can fail even where a participatory model is nominally applied, when the model is misaligned with local sociocultural priorities and expectations around transparency and benefit distribution — a caution this study bears in mind when interpreting the stratified inclusion found among tea tourism stakeholders [18]. Both frameworks are used in the 'Findings and Discussion' section to interpret the varying aspects of community involvement.

2.3 *Employment and livelihoods in community-based tourism*

According to Su et al. [8], the tea tourism sector contributes to direct employment for plantation workers, tour guides, and local artisans, also enabling small-scale entrepreneurs to benefit from direct visitor sales. However, the nature of the tea industry is structured in a manner that limits the interactions of plantation workers with the tourists, leading to a constraint in the economic opportunities created by tourism [4]. Thus, this tension between the cumulative sectoral growth and the uneven distribution of benefits is a recurrent theme in the literature concerning tea tourism and sustainable livelihoods [3]. A recent case study of the Pedro Tea Estate in Nuwara Eliya — within the same Central Province setting examined here — found that tea tourism can support community empowerment and alternative livelihoods when tourism revenue is deliberately linked to community development [17]. In Scheyvens' [10] terms, this suggests economic empowerment is achievable in principle but remains concentrated among tourism-facing roles unless benefit-sharing is deliberately designed to reach the plantation labour force — a distinction this study examines empirically in Section 4.1.

2.4 *Cultural preservation through tourism*

Visitor understanding of Sri Lanka's tea culture is deepened by the contribution of tea tourism to cultural preservation done through storytelling, tea heritage tours, and the demonstration of traditional tea preparation [4]. Nevertheless, there is limited evidence in the literature on whether large, commercially placed factory tours deliver a comparable cultural depth in comparison to smaller, family-run experiences, and this is a comparison this study directly addresses. Where cultural preservation is genuine rather than staged for commercial display, Scheyvens' [10] framework would locate this as a form of psychological and social empowerment — pride and recognition — that can occur independently of economic empowerment, a distinction the findings return to.

2.5 *Social entrepreneurship in rural tourism contexts*

Social entrepreneurship, particularly in rural settings, typically involves local actors providing experience-based tourism by converting cultural and agricultural assets, tea knowledge, land, and craft skills into visitor-facing enterprises such as homestays, boutique tea shops, and artisanal product lines [12]. Initiatives in Sri Lanka authorized by the Government and tourism authorities have sought to encourage such local enterprises through sector-relevant training and by integrating community-led enterprises into the tourism value chain[17][18]. The issue, empirically examined in this study, lies at the intersection of whether these opportunities are accessible to the actors in the tea tourism system, such as plantation workers and smallholders who do not have access to a plethora of resources in comparison to those who already possess capital, education, and external networks. Training-oriented support programmes of this kind sit at the consultation and placation rungs of Arnstein's [11] ladder: they inform and encourage participation without transferring the capital, land access, or decision-making power that would constitute higher rungs of citizen control.

3 METHODOLOGY

3.1 *Research Design*

This study adopts a qualitative, descriptive-exploratory design, selected for its capacity to capture rich, contextual, and interpretive data on stakeholder perspectives and industry dynamics [14]. The analysis presented here is a focused, independent thematic re-analysis of interview data collected for a broader study of sustainable tea tourism in Sri Lanka; the present paper isolates the community involvement dimension of that broader dataset and recodes it against the three refined objectives set out above, rather than reproducing analysis or findings reported elsewhere.

To strengthen the trustworthiness of the analysis, the study applied the established qualitative rigor criteria of credibility, dependability, confirmability, and transferability.

3.2 *Data Collection*

Semi-structured interviews were conducted with five stakeholder groups: tea factory and estate management, plantation workers, tourism service providers, tourism experts and policymakers, and tea tourists. Interviews explored employment conditions and access to tourism revenue, the forms and authenticity of cultural experiences offered to visitors, and the presence, or absence, of locally owned tourism enterprises and the barriers facing them.

3.3 *Sampling and Sample Profile*

Participants were selected using purposive sampling to identify information-rich cases relevant to community involvement in tea tourism [15]. Twenty-three interviews across the five stakeholder groups were available for analysis at the time of writing; one tourism service provider transcript (TSP03) was not available for inclusion, and one tourism expert transcript was excluded as a duplicate record. The resulting sample profile is presented in Table 1.

Table 1. Sample profile of interview participants included in the community involvement analysis

Stakeholder group	Occupation	Code(s)
Industry stakeholders	Tea factory manager	MTF01, MTF02, MTF03
Industry stakeholders	Tea estate superintendent / owner	MTP01, MTP02, MTP03
Plantation workers	Tea plantation worker / plucker	PTW01, PTW02, PTW03
Tourism service providers	Area guide	TSP01, TSP02
Tourism service providers	Tea house / boutique owner	TSP04, TSP05
Tourism service providers	Homestay operator	TSP06
Tea tourists	International tourists (UK, Canada, Australia, Italy, Japan)	TT01–TT05
Tourism experts	Government / tourism authority official; academic	TE01, TE02, TE03, TE04

3.4 *Data Analysis*

Data were analysed using thematic analysis following Braun and Clarke's [13] six-phase approach: familiarization with transcripts, generation of initial codes, and development, review, and naming of themes. Coding was structured deductively around the three refined objectives, employment and economic upliftment, cultural preservation, and social entrepreneurship, while remaining open to inductive sub-themes emerging within each. The empowerment and participation frameworks introduced in Section 2.2 were applied at the interpretation stage to characterise the depth and substance of the involvement reported by each stakeholder group.

3.5 *Trustworthiness and Rigor*

Credibility was supported through data triangulation across five stakeholder groups, whose accounts of the same tourism practices were compared for convergence and divergence, and through investigator triangulation, as the three co-authors independently reviewed the coding of key themes. A shared codebook was developed iteratively during familiarization and applied consistently across transcripts; coding decisions and their rationale were logged to create an audit trail that can be reviewed for con-

sistency.' To limit the influence of researcher assumptions on interpretation, coding was cross-checked between researchers, and disagreements were resolved through discussion and reference back to original transcripts, rather than by a single coder's judgement. Rich contextual detail on the stakeholder groups, occupations, and geographic settings (Table 1) is provided to allow readers to judge the applicability of the findings to other tea tourism contexts.

4 FINDINGS AND DISCUSSION

4.1 *Employment and Economic Upliftment*

Management level participants in factories and estates repeatedly described tea tourism as a source of new employment and diversified income. Tour guiding, retail and hospitality jobs were mentioned several times as jobs that were directly created by tourism activity, and often filled by people living nearby villages.

"Our tea tours provide extra income for our plantation workers, who act as guides." (MTP02 – Tea Plantation Manager)

"We employ local artisans to create handmade teaware, which we sell in our shop as part of our tea tourism experience." (MTP03 – Tea Estate owner)

This pattern was presented as policy success by government and tourism authority stakeholders, who mentioned training programmes designed to provide residents with hospitality and tourism-related skills.

"Community involvement is central to our strategy. We've implemented programs that encourage local entrepreneurs to develop tea-related products and services, such as homestays, guided tours, and handicrafts." (TE01 – Provincial Tourism Ministry Official)

Plantation workers told a very different story. Wages are still linked to rigid daily plucking quotas, generally around 18 kilograms of leaf, with deductions on days when the quota is not met for whatever reason, and workers report little or no interaction with, or income from, tourists who visit the estates where they work.

"Tourists visit the estates, but we don't interact with them much. The tours are managed separately, and the benefits don't trickle down to us. Sometimes, we feel like we are part of the scenery, but our struggles remain unseen." (PTW01 – Plantation Worker)

"Tourists often visit the estate, taking tours and learning about tea production. However, we have little interaction with them. The tours are managed separately, and the additional income doesn't seem to benefit us directly." (PTW02 – Plantation Worker)

"There is potential, yes. If the estate management involved us more, perhaps by training us to lead tours or sell handmade goods to visitors, it could provide additional income and a sense of inclusion. But for now, that connection hasn't been made." (PTW02 – Plantation Worker)

The asymmetry itself was known to and criticized by tourists. A number of visitors spontaneously commented on how tourism revenue seemed to remain with estate owners rather than being passed down to the workers whose labour they had come to see.

"It depends. In some places, the money from tourism stays within the estate owner's hands, while the workers see very little benefit. There should be more transparency on how tourism revenue is shared." (TT04 – Tourist, Italy)

"I am not sure if the benefits reach the workers. The factory shops are expensive, and I assume the profits go mostly to the estate owners. There should be more community-run tea tourism projects where the revenue is shared fairly." (TT05 – Tourist, Japan)

Reviewing Scheyvens' [10] empowerment framework, this pattern indicates economic empowerment at the estate level and a narrow band of tourism-facing guides, retail staff, and coordinators, but the economic disempowerment for the plantation labour force that remains the industry's largest occupational group. As Arnstein [11] describes, plantation workers are at best a rung of tokenism: visible to tourists as part of the attraction but not consulted about tour design or given a share of the revenue it generates. This confirms and refines previous findings that the hierarchical structure of the tea industry constrains workers' ability to capture tourism-generated value [4]. The contrast between TE01's account of community involvement as \"central to our strategy\" and plantation workers' description of near-total exclusion from tourism revenue points to a gap between the rhetoric of inclusive policy and its implementation at es-

tate level — a gap this study's stratified sample makes visible precisely because it draws on worker as well as management voices.

4.2 *Cultural Preservation*

The effects of cultural preservation were very mixed and depended on the scale and type of tourism experience. Big factory visits gave organised, informational content, tea history, processing stages, tasting sessions but some tourists described this as commercially driven, rather than culturally immersive.

"The large tea estate felt more like a business than a cultural experience." (TT05 – Tourist, Japan)

"I felt that some places were more commercialized and focused on selling products rather than creating a deeper connection with the visitors." (TT04 – Tourist, Italy)

Conversely, there was frequent mention of small-scale, family-run and homestay settings as the most culturally authentic, including storytelling, shared meals and direct involvement in traditional practices.

"At the small organic tea farm, the owner demonstrated hand-rolling techniques, and I even helped pluck tea leaves for an hour, which was a humbling experience." (TT05 – Tourist, Japan)

"The most special experience was at Lipton's Seat, where I hiked trough the tea fields at sunrise and had a traditional breakfast with fresh tea made by local family. It was a simple but heartfelt experience, and I felt more connected to the culture than I did in the big factories." (TT04 – Tourist, Italy)

"We host storytelling evenings where our elders share the history of tea with guests." (TSP06 – Homestay Operator)

Estate and factory management acknowledge this gap and are beginning to respond with heritage-oriented additions to the standard factory tour, including a planned tea heritage museum and cultural exchange events between workers and visitors.

"Occasionally, we organise special events where local tea pluckers and factory workers share their experiences with tourists. This creates an authentic and culturally rich experience for visitors." (MTF03 – Tour Coordinator)

Tourists also proposed concrete ways to enrich the cultural content within the standard tour format rather than replacing it, such as storytelling sessions, folk performances, and structured tea rituals.

"Instead of just showing the factory process, estate should include storytelling sessions, folk performances, or tea rituals to share Sri Lankan culture." (TT05 – Tourist, Japan)

This finding qualifies the existing literature treatment of tea tourism as a generally effective vehicle for cultural preservation [4]: the mechanism is real, but its strength is inversely related to the scale and commercial orientation of the tourism format. Scheyvens [10] states that psychological and social empowerment, pride in one's heritage, and recognition from visitors are most visible where economic empowerment is weakest: among small, family-run operators rather than large estates. This raises a critical question the data cannot fully resolve: whether small-scale cultural experiences are more authentic in substance, or simply less commercially mediated and therefore read as authentic by visitors — a distinction with different implications for how estates might expand cultural content without merely staging it.

4.3 *Social Entrepreneurship*

A separate layer of community-level entrepreneurs has developed around tea tourism, homestay operators, boutique tea shop owners, and smallholder estate owners who have diversified into direct-to-visitor sales and experiences.

"My family has been involved in tea cultivation for generations, primarily as smallholders. Fluctuations in global tea prices can impact our profitability, so we've diversified our income by offering plantation tours and operating our tea shop, providing a steady revenue stream." (MTP03 – Tea Estate Owner)

"We prioritize supporting local tea smallholders and estates. By sourcing directly from them, we ensure the quality and freshness of our teas while also promoting sustainable practices and fair compensation for the growers." (TSP04 – Tea House Owner)

"Growing up in Badulla, I always cherished the rich culture and natural beauty of our region. After my children moved abroad, I had extra space in my home and a desire to share our local heritage with oth-

ers. This inspired me to open Suriya Haven Homestay." (TSP06 – Homestay Operator)

What these entrepreneurs share is that they entered tea tourism with resources already in place, land, capital from careers abroad, or established business networks, which plantation workers do not have. Where collective structures exist to reduce this barrier, smaller producers have been able to participate collectively.

"By forming cooperatives, smaller plantations can pool resources to improve infrastructure and market their offerings collectively. Partnerships with government agencies and NGO also provide access to funding and expertise to develop community-based tourism projects responsibly." (TSP01 – Area Guide)

Plantation workers, in contrast, interpreted entrepreneurship as something that could happen to them, rather than a thing that they could initiate, dependent on the decision of the estate management to involve them, rather than a path that they could walk on their own.

"Yes, involving us in tours or workshops could provide additional income and allow us to share our knowledge and stories. It would also help bridge the gap between tourists and workers, fostering mutual respect and understanding." (PTW03 – Senior Tea Plucker)

Again, this gap was independently identified by tourists, and concrete remedies were suggested, particularly direct producer-to-tourist sales channels to allow small farmers to bypass the estate and factory intermediaries that currently dominate tourist-facing commerce.

"Create direct to tourist sales for small farmers. Many small tea growers struggle to sell their tea because big factories dominate the market. If tourists could buy directly from small plantations, it would support local farmers. Introduce a tea plantation homestay program." (TT05 – Tourist, Japan)

This is a "missing middle" in Sri Lankan tea tourism entrepreneurship: there is a visible, active tier of community-based enterprise, but it is occupied almost exclusively by actors who already had the capital, education or networks to enter it, and the plantation labour force that forms the productive base of the industry remains structurally excluded from establishing equivalent enterprises of their own. Most current social entrepreneurship support programmes are at the level of consultation and placation, as per Arnstein's [11] ladder, offering training and encouragement rather than delegating capital, land access or decision-making power to the workers who most need them. This is not simply a skills or motivation gap: plantation workers' exclusion from entrepreneurship tracks closely with their exclusion from land ownership and capital, both legacies of the estate system itself, which suggests that training-only interventions will reproduce the missing middle rather than close it.

4.4 *Cross-Cutting Synthesis*

The same structural pattern applies to all three objectives: involvement that requires visibility for tourists (being observed, photographed, part of the "scenery") is abundant, whereas involvement that requires a transfer of revenue, decision-making authority, or entrepreneurial opportunity is scarce, and concentrated among actors that already have comparatively more resources. Tourists are not responsible for this imbalance. In fact, several directly identified the imbalance and suggested the types of direct, community-run models that would correct it. The barrier is instead in the way tea tourism is organized at the estate and factory level. This means that the key to increasing community engagement in Sri Lanka tea tourism is not so much about generating demand for authentic, community-based experiences from tourists (as the data shows this demand already exists) but rather about reconfiguring the revenue sharing and enterprise support schemes so they are accessible to plantation workers as well as management, service providers, and returnee entrepreneurs.

Read against Arnstein's [11] ladder, none of the three dimensions examined here reach the rungs of partnership or delegated power; read against Scheyvens' [10] framework, economic empowerment is consistently the dimension most withheld from plantation workers even where psychological or social empowerment is present. This suggests the two frameworks are not independent lenses on the same data but mutually reinforcing evidence of a single structural exclusion.

5 CONCLUSION AND RECOMMENDATIONS

5.1 *Conclusion*

The study was aimed at breaking down community engagement in Sri Lankan tea tourism into employment and economic upliftment, cultural preservation, and social entrepreneurship, and empirically examining each of these aspects across five stakeholder groups in the Uva and Central Provinces of Sri Lanka. Findings indicate that community engagement is not a unidimensional condition that tea tourism achieves or does not achieve, but rather a set of distinct forms of involvement that are unevenly distributed across stakeholders. There is real growth in employment, entrepreneurial activity, and management and policy stakeholders report this with enthusiasm. Plantation workers, the least able group to influence how tourism is organized, experience the weakest form of involvement, visibility to tourists without a corresponding share of revenue, cultural recognition, or enterprise opportunity. The better the culture is preserved, the smaller the scale of commerce, in the family-run and homestay settings. The large factory tour, the currently dominant format of Sri Lankan tea tourism, does not necessarily serve the cultural objectives often claimed for it. Meanwhile, social entrepreneurship is concentrated on a resourced middle tier that plantation communities have limited access to despite explicit demand from tourists for the more direct, community-run models that would include them.

5.2 *Recommendations*

Findings give rise to four recommendations. First, estates and factories should pilot structured profit-sharing or tourism-linked wage supplements for plantation workers, the fields and labor of whom are the basis of the of the visitor experience rather than treating tourism revenue as accruing to management alone. second, tour design should include direct, paid worker-visitor interaction, guided picking sessions led by the workers themselves, storytelling roles, and small-group tastings, rather than channeling all guiding functions through separately hired staff. Third, government and industry training programmes for tourism entrepreneurship need to be complemented by access to capital and land-use flexibility. Training alone has not proved sufficient to move plantation workers from consultation into ownership of tourism enterprises. Fourth, tourism authorities and cooperatives are well placed to pilot direct-to-producer sales and homestay placements with plantation families as low-risk, demand-tested interventions, because tourists are asking for them, rather than having to build visitor demand from scratch.

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AI-driven ESG Reporting and Greenwashing in Sri Lanka

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ABSTRACT: Artificial intelligence can assist sustainability reporting while making unreliable estimates and unsupported narratives harder to detect. This doctrinal study examines Sri Lankan corporate, securities, consumer and disclosure law, using publicly available authorities searched to 30 September 2026. A functional comparison of the European Union, United Kingdom, Australia and India evaluates disclosure, substantiation, assurance, AI governance, enforcement and liability. Existing Sri Lankan law already reaches several AI-assisted misstatements, but liability depends on the communication, responsible actor and statutory fault threshold. Two hypothetical scenarios demonstrate these distinctions. The principal weaknesses concern operational verification expectations, evidence preservation and uneven regulatory coverage rather than an absence of corporate responsibility. The paper proposes targeted listing-rule controls, proportionate assurance, legally authorised cooperation and legislation only where existing powers are insufficient. Its contribution is an accountability framework that connects AI-related reporting risks to legal elements and feasible reform choices in a developing capital market.

Keywords: ESG reporting, greenwashing, artificial intelligence, corporate accountability, sustainability disclosure

1 INTRODUCTION

Environmental, social and governance (ESG) reporting communicates an organisation's sustainability-related performance, risks and governance. Sustainability-related financial disclosure is a narrower category: IFRS S1 focuses on risks and opportunities capable of affecting cash flows, access to finance or the cost of capital, while IFRS S2 addresses climate-related matters [1], [2]. Neither the term ESG nor a favourable ESG rating necessarily signifies compliance with these standards. This distinction matters when an annual report combines required financial disclosures with voluntary claims about environmental benefits.

Sri Lanka is applying local SLFRS S1 and S2 requirements in phases. The Colombo Stock Exchange (CSE) amended its annual-report rule with effect from 18 February 2025 [3]. The published roadmap covers the largest 100 listed entities from reporting periods beginning on or after 1 January 2025, Main Board entities from 2026, and other listed entities except the Empower Board from 2027; later categories extend to 2030 [4]. Adoption creates a practical question: who must answer for an inaccurate sustainability statement when software extracts its inputs, estimates missing values or drafts the explanation?

The legal problem is not that a machine becomes the corporate speaker. The problem is whether the applicable rule reaches the communication and whether the evidence establishes its particular elements. For example, section 130 of the Securities and Exchange Commission of Sri Lanka Act No. 19 of 2021 (SEC Act) addresses materially

misleading information with a likely market-price or trading-volume effect and includes a reasonable-care limb [5]. That differs from the intention-based route for information furnished to a market institution under section 88. Treating all AI errors as fraud, or requiring fraud for every route, would therefore be equally inaccurate.

This paper asks: first, how do existing Sri Lankan accountability routes apply to AI-assisted ESG statements; second, what verification and enforcement limitations remain; and third, which foreign regulatory functions can be adapted through lawful, proportionate domestic measures? The contribution is an element-based accountability framework, tested through two hypothetical scenarios and a structured comparison. The paper does not measure AI adoption, establish the incidence of Sri Lankan greenwashing or claim that a proposed reform has demonstrated effectiveness.

2 CONCEPTS AND LITERATURE

2.1 *Reporting and misleading environmental claims*

An AI-assisted ESG statement is a published corporate statement whose data selection, estimation, classification or wording has been materially influenced by an AI system. It includes numerical estimates and narrative claims. In this paper, material AI use means a contribution capable of affecting a reasonable intended user's understanding of a significant claim, its boundaries or its evidential basis. This is an analytical threshold for proposed controls, not an existing statutory definition. Routine spelling correction ordinarily falls outside it. Financial-reporting materiality, securities-market materiality and a consumer's potentially misleading impression remain separate legal tests.

Greenwashing is used here to describe environmental communications that create a misleading impression through falsehood, omission, selective emphasis or unsupported claims. It is a category of conduct, not a claim that Sri Lankan law contains a free-standing offence with that name. Social or governance misstatements may engage similar legal routes but are not automatically environmental greenwashing. Research on greenwashing explains how selective communication can disconnect public impressions from underlying performance [6]. Recent legal scholarship connects effective green claims to market regulation rather than assuming that disclosure alone ensures meaningful consumer choice [7]. The resulting question is whether the recipient can evaluate the claim against evidence of the same scope.

2.2 *AI risk and corporate responsibility*

The reporting process can involve document extraction, model-based estimation, classification and generative drafting. These functions should not be conflated. An emissions estimate produced by a statistical model raises questions about assumptions and uncertainty; a language model inventing a certification raises a different evidential problem. ESG-data research identifies inconsistency and weak comparability [8]; ratings research shows that different measurement and aggregation choices can produce divergent assessments [9]. These studies explain underlying information problems, not the probability of a particular AI error.

AI-specific propositions require separate support. Work on large language models cautions against equating fluent text with grounded meaning [10]. NIST's Generative AI Profile identifies confabulation, information-integrity risks and inappropriate human reliance, and recommends attention to provenance, testing and governance [11]. Applied to ESG reporting, the inference is that unsupported statements may pass through a reporting process when reviewers assess presentation without checking source records. No empirical claim about Sri Lankan issuers follows from that inference.

Corporate-law analysis of AI considers changes to control and liability when corporate functions become automated [12]. Algorithmic-accountability scholarship also explains why access to source code alone is an incomplete substitute for mechanisms that make decisions testable [13]. These insights support examining the human approval process, the allocation of authority and retrievable evidence. They do not establish a Sri Lankan rule of strict liability for AI use or make an external software supplier a director.

2.3 *Substantiation verification and assurance*

Substantiation means holding evidence sufficient to support a claim's content and scope when it is communicated. Verification means checking that evidence, assumptions and outputs against specified criteria; it may occur internally and does not itself imply independence. Assurance is a distinct engagement in which an independent practitioner evaluates sustainability information against suitable criteria and expresses a conclusion. Limited assurance involves a lower level of assurance and less extensive procedures than reasonable assurance; neither guarantees an error-free statement [14].

Research on sustainability assurance shows that its credibility depends on how practitioners develop and communicate the engagement, not merely on attaching an assurance label [15]. This supports specifying the subject matter, criteria, exclusions, level and provider independence. A model's own confidence score, an ESG rating and a financial-statement audit are not interchangeable with assurance of the sustainability information at issue. The literature therefore supplies an integrated premise: accountability requires a legally responsible decision-maker and a defensible evidential process, while assurance supplements that process within its defined scope.

3 METHODOLOGY

3.1 *Sources and research boundaries*

The study uses doctrinal interpretation and functional comparison. The research cut-off is 30 September 2026. English-language, publicly accessible or publicly indexed materials were searched through official repository pages and web searches restricted to the relevant institutional domains. Sri Lankan sources included the Department of Government Printing and Parliament, the Registrar of Companies and LawNet, the SEC, CSE, Consumer Affairs Authority (CAA), Data Protection Authority (DPA), Central Bank of Sri Lanka (CBSL), CA Sri Lanka and the IFRS Foundation. Comparative sources included EUR-Lex, the FCA, ASIC, SEBI and India's Department of Consumer Affairs. Scholarly materials were traced through publisher and university repositories and citation links. No proprietary database search or empirical fieldwork is claimed.

Search families combined the jurisdiction or statute with 'sustainability disclosure', 'SLFRS S1', 'SLFRS S2', 'greenwashing', 'misleading environmental claims', 'artificial intelligence', 'reasonable care', 'directors reliance', 'assurance', 'commencement', 'Gazette', 'rules' and 'information sharing'. Statutory section numbers and instrument identifiers were then searched separately. Sources were included where they established a relevant duty, remedy, commencement position, technical assurance distinction or analytical framework. Unenacted proposals, expired arrangements and earlier versions were retained only where necessary to explain change and were labelled accordingly. Vendor marketing, unverified summaries and commentary unsupported by the underlying authority were excluded from statements of law.

The hierarchy was legislation and commencement instruments, applicable rules and standards, judgments, official regulatory explanations, then scholarship. A statutory provision's operative wording controls over a summary or an older webpage. Several official PDFs could be located through indexed passages but could not be opened directly during verification; official regulator notices and reproduced statutory passages were used for the specific propositions identified. This access limitation restricts the completeness of the update exercise, particularly for negative findings. It does not justify treating a draft Bill as enacted legislation.

3.2 *Interpretation and negative findings*

Each accountability route was analysed by actor, communication, jurisdictional trigger, fault threshold, required evidence, enforcement mechanism, remedy and limitation. Table 1 condenses the resulting analysis. Two deliberately constructed scenarios then test whether the same AI-related event produces different legal outcomes as the recipient, knowledge or market effect changes. These are analytical illustrations, not observed incidents or evidence of enforcement practice.

Negative propositions received a narrower formulation. Searches for a general AI enactment, a cross-sector greenwashing-

specific rule, a general mandatory sustainability-assurance obligation and a published greenwashing coordination protocol were checked against the relevant official source categories and positive duties already identified. The finding is that no such general instrument was located within this search scope by the cut-off. It is not proof of universal absence, non-public arrangements or informal cooperation. Nor does it negate sectoral requirements, reasonable-care duties, voluntary assurance or later changes. An older jurisdictional profile is used as a dated baseline and read alongside subsequent regulator and standard-setter materials.

3.3 *Functional comparison and limits*

The comparator selection is purposive. The EU illustrates combined reporting and consumer legislation; the UK provides a focused financial-services supervisory rule; Australia supplies litigated misleading-claims enforcement and reporting-liability transitions; India illustrates phased listed-entity requirements alongside consumer-claim controls in a large emerging economy. These are complementary functions, not representative samples or a ranking of legal systems. India's scale and supervisory resources also differ substantially from Sri Lanka's.

All four are assessed against the same dimensions: disclosure perimeter, substantiation, assurance, AI governance, enforcement, liability and implementation burden. Functional comparison permits examining responses to a common problem without treating identically named rules as equivalent [16]. Research on legal transplantation further cautions that statutory borrowing cannot substitute for institutional fit [17]. Accordingly, the comparison supports conditional design choices rather than causal claims about regulatory effectiveness. It cannot establish actual enforcement capacity, compliance costs or investor outcomes without further empirical work.

4 SRI LANKAN ACCOUNTABILITY

4.1 *Disclosure perimeter and reporting assurance*

CSE Rule 7.5(a)(i)(b) requires annual reports to include disclosures prepared and published in accordance with Sri Lanka Sustainability Disclosure Standards [18]. The applicable reporting cohort and transitional relief must still be determined. The published Sri Lankan roadmap includes additional relief concerning Scope 3 emissions and certain anticipated financial effects and scenario disclosures [4]. An issuer should not be characterised as non-compliant simply because information is lawfully deferred. Conversely, relief from supplying a metric does not authorise an affirmative, misleading claim about that metric.

The Sri Lanka Accounting and Auditing Standards Act No. 15 of 1995 supplies the statutory framework for accounting and auditing standards and oversight of specified business enterprises [19]. The express listing-rule requirement is the clearest route for the listed-issuer sustainability obligation examined here. It is unsafe to infer that every sustainability statement automatically falls within every enforcement provision directed at financial statements under the 1995 Act. The standard-setting function, the duty to report and the duty to obtain assurance require distinct legal bases.

CA Sri Lanka's announcement of 2 September 2026 confirms adoption of SLSSA 5000, effective for assurance engagements concerning periods beginning on or after 15 December 2026, or information as at a date on or after that date [20]. A technical standard governing an assurance engagement does not itself compel every reporting entity to commission one. The IFRS Foundation's June 2025 profile described a general assurance requirement as under consideration; no later general mandate was located in this study [4]. That qualified finding should not be presented as a claim that no Sri Lankan entity obtains assurance.

4.2 *Securities statements and regulatory filings*

Section 130 of the SEC Act is central. It concerns a statement or disseminated information that is false or misleading in a material particular, is likely to raise, lower, maintain or stabilise the market price or trading volume of relevant securities, and is made without reasonable care to check accuracy, or with actual or reasonably expected knowledge of the material falsehood [5, s. 130]. The alternatives matter: a claimant or regulator need not establish dishonest intent

to satisfy the reasonable-care limb. Nevertheless, a reporting error alone is insufficient; material falsity and the statutory market nexus also require proof.

Relevant evidence includes the statement's audience, dissemination and timing, the significance of the represented environmental benefit, source records, model assumptions, omitted qualifications and the checks performed. Evidence of actual price movement may assist but is not the wording of the statutory 'likely' effect test. An issuer-approved annual report or market announcement can be relevant even if its particular environmental statement was voluntarily included. A consumer advertisement without the requisite market connection should not automatically be analysed under section 130.

Sections 87 and 88 protect different information channels. Section 87 imposes due care when information is furnished to the SEC under the Act or its subordinate instruments, including specified signed or electronically lodged documents. Section 88 concerns misleading statements or reports furnished to a licensed market institution in relation to information a listed company must provide; its wording requires attention to intent to deceive and knowing and wilful authorisation or permission [5, ss. 87-88]. An innocent AI error therefore does not by itself establish the section 88 offence. Upload logs and a signatory's authority matter, as does proof that the filing fell within the statutory channel.

Part V contraventions engage the criminal route under sections 147-149 and the civil routes under sections 151-152. Section 151 permits recovery of loss or damage caused by or through reliance on specified misconduct, including section 130, without requiring a prior prosecution or conviction. Recovery still requires the statutory connection to loss. Section 178 separately permits administrative action for specified breaches outside Part V, including market-institution rules; it expressly excludes Part V offences [5]. A regulator cannot simply relabel section 130 misconduct as a section 178 offence to avoid the prescribed procedure. A distinct listing-rule breach must be separately established.

4.3 *Directors and authorised corporate publication*

Section 187 of the Companies Act No. 7 of 2007 requires a director to act in good faith in what the director believes to be the company's interests. Section 189(a) prohibits reckless or grossly negligent conduct, while section 189(b) separately requires the degree of skill and care reasonably expected of a person with that director's knowledge and experience [21]. The second limb should not be collapsed into a universal gross-negligence threshold. A director with relevant expertise, confronted with unexplained discrepancies in an emissions model, presents a different case from one receiving a properly tested estimate from competent personnel.

Section 190 permits reliance on specified human sources: an employee, an appropriately competent professional adviser or expert, or another director or qualifying committee. Reliance requires good faith, proper inquiry where circumstances indicate its need, and no knowledge that reliance is unwarranted [21, s. 190]. An AI system is not itself one of the listed persons. Where an employee supplies an AI-assisted report, the statutory inquiry concerns reliance on that employee and the circumstances calling for investigation. A vendor's assurance that its product is accurate does not conclusively discharge the director's duty.

Board papers, reporting responsibilities, qualifications, known limitations, challenges raised and responses are therefore important evidence. Corporate duties primarily protect the company; a shareholder does not automatically receive a personal damages claim for every loss. Proceedings on the company's behalf may require leave under section 234. Section 511, addressing knowingly and wilfully false material statements in documents required by or for the Act, is also narrower than a general prohibition on inaccurate publicity [21]. An environmental statement's inclusion in a company publication does not dispense with that document requirement or mental element.

Table 1. Sri Lankan accountability routes for AI-assisted ESG statements

Route and actor	Statement and threshold	Evidence	Enforcement and remedy	Principal limitation
Listing rules Listed entity and responsible board	Required annual-report disclosures; applicable cohort, standard and relief [18], [5, s. 89].	Report, reporting period, compliance assessment and approval records.	CSE compliance processes; SEC action within its powers, including s. 178 for a distinct qualifying breach.	A reporting duty does not itself establish fraud or assure every voluntary claim.
SEC Act s. 130 Maker or disseminator	Material falsity; likely market-price or volume effect; lack of reasonable accuracy checks, or actual/constructive knowledge [5].	Source data, market relevance, assumptions, warnings and checking records.	SEC investigation; Part V criminal route; private loss claim under s. 151 and SEC civil route under s. 152.	Market nexus and fault must be proved; private recovery additionally requires the statutory connection to loss.
SEC Act s. 87 Person furnishing, signing or submitting	Qualifying information to the SEC; due care concerning material falsity [5].	Request or filing basis, signed document, electronic authentication and review record.	SEC investigation; statutory offence and available non-Part V enforcement mechanisms.	A public statement alone does not establish the required SEC filing channel.
SEC Act s. 88 Responsible maker or authoriser	Misleading required information to a licensed market institution; intention/knowledge requirements in the statutory wording [5].	Filing obligation, communications, authorisation and evidence of intent or knowing permission.	Statutory offence route; any separate regulatory breach requires its own basis.	An unexplained AI error alone does not prove deceptive intent or knowing and wilful authorisation.
Companies Act Director; relevant document maker	Ss. 187, 189 and 190 govern conduct and reliance; s. 511 requires a knowingly and wilfully false material statutory document [21].	Expertise, board papers, warnings, inquiries, advice and document status.	Company remedies; derivative proceedings with leave under s. 234; s. 511 offence where established.	Duty to company differs from personal investor redress; the two limbs of s. 189 must remain distinct.
CAA Act ss. 30–31 Trader	Misleading trade conduct or specified false product/service representations; no identical s. 88 intent test [22].	Advertisement, audience, actual product attributes and certification evidence.	CAA investigation and offence procedures; s. 13 redress only where its separate conditions are met.	Trade/supply connection required; investor-reporting and consumer-protection tests differ.

Source: doctrinal synthesis of the cited legislation and CSE rules. The table identifies potential routes; it does not determine liability in an actual case.

4.4 *Consumer and sectoral claims*

CAA Act section 30 prohibits a trader's misleading or deceptive conduct, or conduct likely to mislead or deceive a consumer or another trader, in trade or business. Section 31 addresses specified false representations in supplying or promoting goods or services, including claims about characteristics, benefits and approval [22]. Unlike section 88 of the SEC Act, these provisions do not express the same intention-to-deceive threshold. The analysis should begin with the claim's overall impression and the statutory trade or supply connection, without importing securities-market materiality as an extra requirement.

A statement that packaging is fully biodegradable requires evidence about the material, conditions and relevant timeframe. A narrowly accurate laboratory result can still fail to support an unqualified claim about ordinary disposal. Consumer-facing promotional claims engage the CAA framework even where the advertiser has no duty to publish a sustainability report. CAA investigation and statutory offence procedures remain relevant, while compensation, replacement or refund under section 13 depends on that section's separate conditions and complaint process; it is not an automatic remedy for every breach of sections 30-31 [22].

Sectoral instruments also matter. CBSL's Banking Act Directions No. 5 of 2022 address sustainable-finance governance and management for licensed banks [23]. These directions neither regulate every issuer nor supply a general cross-sector definition of greenwashing. Their existence demonstrates

why a finding of no general rule must not be confused with a regulatory vacuum.

4.5 *Personal data and commencement*

The Personal Data Protection Act No. 9 of 2022 (PDPA) is relevant where a reporting process handles identifiable employee, customer or supplier data. It is not a general statute governing the truth of environmental claims [24]. Its commencement position requires particular care. Gazette Extraordinary No. 2366/08 of 8 January 2024 originally scheduled Parts I, II, III and VII for 18 March 2025. Gazette No. 2427/34 of 14 March 2025 repealed the relevant paragraph of that order [25], [26]. The 2025 Amendment Act replaced the commencement formula with ministerially appointed dates and removed the earlier statutory timing provisions [27].

The DPA's current register lists Gazette Extraordinary No. 2498/16 of 22 July 2026. The Authority's associated operationalisation notice identifies 1 January 2027 for sections 2 and 3 and Parts I and III [28], [29]. Consequently, these provisions are scheduled, rather than already operative, at this paper's cut-off. The notice does not establish commencement of every remaining Part. In particular, the automated-decision right in section 18, located in Part II, should not be represented as a presently enforceable remedy on this evidence. Even when applicable, it concerns specified decisions affecting individuals, not an undifferentiated right to challenge every AI-assisted ESG sentence. Each relevant provision's commencement must be checked separately.

5 APPLICATION TO HYPOTHETICAL SCENARIOS

5.1 *An issuer publishes an unsupported reduction*

Assume that a listed manufacturer publishes an annual report stating that its total value-chain emissions fell by 30 per cent. An AI-assisted process fills missing supplier data with favourable estimates and drafts an unqualified reduction claim. Internal emails identify the missing data, but management publishes without reconciling the estimates. These facts are hypothetical and do not describe an identified company.

The first question is the claim's scope. A reduction in measured operational emissions would not support an unqualified reduction across the value chain. The relevant cohort may benefit from Scope 3 reporting relief, but that does not establish the truth of the voluntary broader statement. For section 130, the SEC or claimant would need evidence of material falsity and the likely effect on the relevant securities' price or trading volume. If sustainability-linked finance or investor communications made the claimed reduction commercially significant, the market nexus becomes more plausible, but must still be proved [5].

The unaddressed warnings and missing reconciliation could support failure to take reasonable care under section 130(a). They do not automatically prove the intention required for section 88. That route also requires a qualifying statement to a licensed market institution. Section 87 becomes relevant if the information is furnished to the SEC in its prescribed channel. The analysis therefore depends on what was submitted, to whom and under which obligation, rather than describing a single generic 'ESG offence'.

For directors, section 189(b) and the section 190 inquiry conditions focus attention on the warnings, expertise and review undertaken [21]. A civil claim for investor loss under section 151 additionally requires the requisite causal or reliance connection; proof that an algorithm erred is not enough. Retaining the supplier dataset, estimation method, output versions, internal warnings and approval records would help distinguish an unreasonable reporting process from a defensible estimate that later proved inaccurate. A subsequent correction may mitigate continuing harm without necessarily erasing the original contravention.

5.2 *A product advertisement invents certification*

Assume instead that a consumer-goods company uses a language model to prepare packaging copy claiming that a product is independently certified as carbon neutral. No such certification exists. The marketing team approves the text after checking grammar but not the certification claim. This is a separate hypothetical illustration.

CAA section 31 is directly relevant to the alleged approval, characteristics or benefits

of the product, while section 30 addresses the overall misleading impression [22]. The evidence would include the advertisement, product and sales connection, intended audience, certification registers, internal approval records and any supporting assessment. The trader's decision to publish the generated wording links the communication to the business. It does not follow that every employee or software provider is personally liable; their liability requires a separate legal basis and the necessary facts.

The claim's voluntary nature does not remove it from consumer law. Conversely, the absence of a sustainability-reporting obligation does not establish a listing-rule breach, and section 130 would require an independently proven securities-market nexus. If management later repeats the assertion in investor materials, a second regulatory route may arise. A supply contract allocating verification work to an external provider may support contractual recourse, but does not by itself extinguish the trader's statutory obligations. The two scenarios expose overlapping accountability with different thresholds, rather than an AI-created immunity.

6 COMPARATIVE ANALYSIS

6.1 *Regulatory models and their boundaries*

The EU separates corporate reporting from consumer claims. The Corporate Sustainability Reporting Directive established sustainability reporting and assurance requirements [30]. Directive (EU) 2026/470 narrows the principal reporting perimeter to undertakings exceeding both 1,000 employees and EUR 450 million net turnover, subject to the applicable individual or group provisions, transposition and transitional arrangements; it retains limited assurance and removes the earlier reasonable-assurance standard-setting requirement [31]. These changes demonstrate the political and administrative importance of reporting costs. They should not be described as if all Member States' domestic obligations changed identically on the Directive's publication date.

Directive (EU) 2024/825 adds targeted consumer protections concerning generic environmental claims, sustainability labels and specified offset-based product claims. Member States were required to apply the implementing measures from 27 September 2026 [32]. The distinction between a Directive and its national implementation remains material. The AI Act is a separate, use-case-based instrument: internal ESG drafting is not automatically an Annex III high-risk use. Article 50 contains particular transparency obligations and an editorial-control exception relevant to public-interest text; it does not establish a universal obligation to label every internally AI-assisted corporate report [33].

The UK FCA's ESG 4.3.1R anti-greenwashing rule applies to relevant sustainability references concerning products or services by authorised firms and took effect on 31 May 2024. FG24/3 explains expectations that claims be correct and substantiated, clear, complete and fairly comparative [34], [35]. This is a useful operational model for claim review, but its perimeter is financial services. It neither establishes a general company-reporting duty nor requires assurance of every sustainability claim. Its substantiation principles can inform Sri Lankan guidance only after identifying the domestic statutory hook.

Australia demonstrates enforcement through existing misleading-conduct law. The Federal Court imposed AUD 11.3 million on Mercer and AUD 12.9 million on Vanguard for misleading sustainability-related representations [36], [37]. Neither decision establishes a special AI-greenwashing doctrine. Their relevance is that published claims must correspond to the actual investment methodology and implementation. Australia's 2024 reporting legislation separately introduced mandatory climate reporting [38]. Transitional modified-liability provisions protect specified statements within covered reports while preserving criminal proceedings and ASIC action; they are not a general licence for unsupported public marketing [39].

India combines listed-entity reporting with consumer-claim supervision. SEBI's BRSR framework covers the top 1,000 listed entities, while BRSR Core introduced phased requirements for selected indicators [40], [41]. The circular of 28 March 2025 allows assessment or assurance and makes relevant value-chain disclosures and their associated assessment or assurance voluntary under the revised framework [42], [43]. Assessment should not be assumed to deliv-

er the same engagement or assurance level. India's 2024 CCPA guidelines separately require substantiation and adequate disclosure of environmental claims [44]. This combination illustrates phased coverage, but its transplant would depend on Sri Lanka's provider market and supervisory resources.

Table 2. Functional comparison of selected regulatory mechanisms

Dimension	European Union	United Kingdom	Australia	India
Disclosure perimeter	CSRD reporting; 2026 scope narrowing subject to transposition and transitions [30], [31].	FCA anti-greenwashing rule concerns authorised firms' relevant product/service communications [34].	Mandatory climate-reporting regime plus financial-product representations [38].	BRSR for top 1,000 listed entities; phased BRSR Core [40], [41].
Substantiation	Targeted consumer restrictions, including generic and specified offset-based claims [32].	Guidance explains evidential support, completeness and fair comparisons [35].	Claims must match the actual investment screens and implementation [36], [37].	CCPA guidelines require credible evidence and adequate claim boundaries [44].
Assurance	Limited assurance retained for covered reporting; national implementation matters [31].	The selected anti-greenwashing rule does not itself mandate assurance of each claim.	Reporting legislation provides a separate assurance architecture; it differs from advertising enforcement [38].	BRSR Core permits assessment or assurance; relevant value-chain arrangements are voluntary [42], [43].
AI governance	AI Act duties depend on role and use; no blanket internal-ESG-drafting classification [33].	Technology-neutral claim responsibility under the selected rule.	The cited greenwashing cases are not findings of AI-specific liability.	The selected BRSR and CCPA instruments do not create a separate AI-liability regime.
Enforcement and liability	Reporting and consumer mechanisms operate through distinct legal instruments and domestic enforcement.	FCA supervision within its financial-services jurisdiction; separate from universal corporate liability.	Court penalties for misleading claims; modified reporting liability preserves ASIC and criminal action [39].	SEBI listed-entity supervision and CCPA consumer enforcement have different statutory perimeters.
Transfer condition	Avoid importing broad reporting costs without domestic capacity assessment.	Adapt verification guidance only within the Sri Lankan enabling power.	Retain enforceability; confine any transition protection to defined, reasonably based statements.	Phase coverage and assess provider independence; assessment and assurance are not equivalent.

Source: the authorities cited in section 6. This comparison concerns selected mechanisms, not every law in each jurisdiction. Transfer conditions are this paper's normative inferences.

6.2 *Synthesis for Sri Lanka*

Table 2 reveals a common function across different legal forms: an organisation should be able to connect a material claim to evidence about the same product, portfolio, reporting boundary and period. The inference for Sri Lanka is that a claim-evidence record could operationalise existing care and disclosure duties before creating an entirely new liability architecture. The legal source of that obligation must nevertheless be explicit. The FCA model cannot simply be applied to unregulated traders, and the EU consumer blacklist cannot automatically govern an issuer's annual report.

The comparison also exposes trade-offs. EU scope reduction and India's revised assurance options show that wider formal coverage can encounter cost and capacity constraints. Australia's proceedings show the importance of enforceable claims, but penalties alone do not establish how well routine supervision prevents misconduct. A transition protection may encourage useful estimates while weakening private redress if drafted too broadly. Sri Lanka should therefore distinguish honest, appropriately qualified estimates from statements unsupported when made and evaluate reform by improved evidence and correction, rather than by the number of disclosures produced.

7 REFORM DESIGN AND LEGAL FEASIBILITY

7.1 *Guidance and targeted listing requirements*

The first step should be a consultation-led SEC and CSE explanation of how existing

obligations apply to sustainability claims, accompanied by examples of adequate boundaries, sources, estimates and correction procedures. Guidance must distinguish interpretation from a new binding requirement. Section 178's reference to guidelines does not confer unlimited substantive law-making power. A document called guidance cannot validly expand jurisdiction, remove a statutory mental element or create new private damages rights [5].

For listed entities, the CSE rule-approval structure in section 64 and the SEC's rule-making power under section 183 provide relevant routes to examine for targeted disclosure and recordkeeping requirements. The SEC-approved 2025 amendment to Rule 7.5 is a concrete precedent for updating annual-report obligations [3]. It does not prove that any proposed AI or assurance requirement is authorised. Each measure needs a specified enabling provision, proper adoption and publication, and a proportionate connection to securities regulation. A cross-sector duty extending to all traders would require another sufficient statutory basis or legislation.

A proposed material-AI-use control should identify an accountable manager, record the task and data sources, explain significant estimation assumptions, preserve relevant versions and document competent human review. Public disclosure should concern significant methodological effects and limitations, rather than routine software use or confidential prompts. Reviewers should compare claims with source evidence, investigate discrepancies and approve corrections. These are proposed operational expectations, informed by the existing care standards; the paper does not claim that every listed company already has an express duty to keep every AI prompt.

7.2 *Proportionate assurance and implementation cost*

After a provider-capacity and cost assessment, a pilot could introduce limited assurance of selected material sustainability metrics for the largest listed entities. SLSSA 5000 supplies an engagement framework, while a binding obligation to obtain assurance still requires an appropriate legal instrument [20]. Any eventual expansion should define the subject matter and level, require independence, and make exclusions visible. Where existing delegated powers are insufficient, Parliament must supply the authority; a standard-setter's technical adoption cannot fill that gap.

Smaller entities should receive model claim-evidence registers, training, phased dates and requirements tied to materiality. A firm with limited AI use should not have to commission a general audit of every software system. Costs include data remediation, supplier information, skilled review, record retention and assurance fees. A poorly calibrated mandate may reduce informative voluntary disclosure, favour expensive providers or give a superficial assurance label undue credibility. These are prospective risks to be tested through consultation, not quantified findings. Pilot evaluation should track correction quality, unresolved evidence gaps, provider availability and compliance effort before extending coverage.

7.3 *Legislation where a genuine coverage gap remains*

Legislative review should begin by testing the reach of SEC Act section 130 and CAA Act sections 30-31. Their existence makes a blanket assertion that misleading sustainability claims are lawful untenable. A targeted amendment may nevertheless be justified where a material claim falls between regulated communication channels or where a uniform duty to retain reasonable contemporaneous substantiation is desired [5], [22]. Parliament would need to define the protected audience, claims, evidence standard, responsible persons and enforcement powers, and resolve overlap with existing remedies.

Any new civil or administrative route should distinguish negligent unsupported claims from deliberate deception and avoid mechanically reversing burdens in criminal proceedings. A narrowly framed protection for forward-looking estimates could require a disclosed basis, reasonable grounds, material assumptions and timely correction, while excluding knowingly false statements. Retaining regulator action would reduce the risk that transitional relief disables oversight. Australia's limited statutory protection is a design reference, not authority for a Sri Lankan safe harbour [39]. New offences, expanded sanctions or additional private causes of action require legislation unless a valid existing delegation specifically permits the measure.

7.4 *Coordination within existing powers*

SEC Act sections 170 and 171 already provide an express foundation for regulatory agreements and cooperation, including arrangements with domestic supervisory authorities [5]. The narrower problem identified by this search is the absence of a located, published greenwashing-specific operational protocol, not the absence of all power to cooperate. A protocol could allocate lead responsibility by communication and harm, define referral triggers, pool technical expertise and coordinate requests to reduce duplication.

The power of each receiving authority must be checked independently. A memorandum cannot override secrecy obligations, privilege, procedural fairness or applicable data rules. Where lawful information sharing is unavailable, legislation or another authorised mechanism is necessary. Coordination should preserve each regulator's mandate and avoid assuming that one regulator's finding proves all elements of another's offence. Institutional costs include specialist reviewers, training and secure evidence management. These limits support incremental implementation and published guidance rather than an immediate, resource-intensive general AI regulator for ESG reporting.

8 CONCLUSION

Existing Sri Lankan law provides several routes for accountability when a company publishes an AI-assisted ESG misstatement. Section 130's reasonable-care route, the distinct filing duties in sections 87-88, directors' obligations and consumer-claim rules address different actors and communications. Neither AI involvement nor voluntary publication establishes immunity; neither establishes liability without the relevant legal elements. The two scenarios show why verification records, reporting boundaries, knowledge and market or consumer context determine the analysis.

The comparative contribution is a framework for selecting regulatory functions rather than transplanting entire foreign regimes. Sri Lanka can begin with carefully grounded guidance, targeted listing requirements and evidence retention, then test proportionate assurance and coordination. Legislative change should address demonstrated coverage or remedial gaps. The conclusions remain doctrinal: public-source access limits negative findings, and the study does not establish actual adoption, enforcement performance or compliance cost. Empirical research with issuers, regulators and assurance practitioners is the next step for testing feasibility.

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The Impact of Social Media Influencer Marketing on Generation Z Purchase Intention in Sri Lanka

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ABSTRACT: Digital technology is changing marketing – indeed social media is an important tool in business communication. Influencer marketing enables brands to market their products using influencers on platforms like Instagram, TikTok, Facebook, and YouTube. This study aims to explore how the credibility, expertise, attractiveness and trustworthiness of influencers influence purchase intention of Generation Z consumers in Sri Lanka. Structured online questionnaires were used in the study, which adopted a quantitative approach. Descriptive, correlation and multiple regression analysis were used to analyze the data. Results indicate that all four attributes have positive and significant impacts on the purchase intention, and the most powerful is trustworthiness. The study offers practical tips on how to succeed in influencer marketing.

Keywords: Generation Z, social media, influencer marketing, purchase intention, influencer credibility

1 INTRODUCTION

Social media has become a crucial part of today's marketing strategy, as digital technology has revolutionized how businesses interact with consumers. Platforms like Instagram, TikTok, Facebook, and YouTube allow businesses to connect with their target audience directly by creating interactive content and personalising their communication. Social media influencer marketing is one of the most popular digital marketing tactics, as it enables brands to sell products via influencers with whom they have developed trust and good relationships with their followers. Social media influencers produce content which can impact consumers' opinions, attitudes and buying choices. Influencer marketing goes beyond mere endorsements to the concept of authenticity, credibility, and engagement with followers. Past research has demonstrated that the credibility, expertise and attractiveness of the influencers are associated with the trust and purchase intent of consumers. As a result, businesses are increasingly working with influencers to increase brand awareness, engagement and conversions across different industries.

Generation Z is one of the influential consumer groups in the digital age. They are digital natives and use social media extensively to find products, to research other options, read reviews, and decide on a purchase. The fact that they rely on influencer recommendations shows the need to understand the impact of influencer marketing on their purchase decisions. In Sri Lanka, the rise of social media has spurred business growth in all sectors, from fashion, beauty and food to tech and lifestyle, and it has led to the adoption of influencer marketing. Nevertheless, although it is becoming a popular marketing strategy, there is scarcely

any empirical research that investigates the effectiveness of influencer marketing in the Sri Lankan environment. Purchase intention may be impacted by cultural values, social norms and local market conditions in a different way than in international markets. Hence, the study aims to analyse the impact of social media influencers' credibility, expertise and attractiveness on the purchase intention of Generation Z consumers in Sri Lanka. The findings are slated to further academic knowledge. For Generation Z consumers in Sri Lanka, the purchase intention is highly positively influenced by the influencer's credibility.

2 LITERATURE REVIEW

The rise of social media has altered the mode of communication adopted by businesses through switching from conventional marketing to digital marketing practices. Generation Z has become an important consumer group because of their digital literacy, regular usage of social media and their reliance on online information in making purchasing decisions. Consequently, social media influencer marketing is becoming a popular practice for companies to influence the attitudes of consumers and increase their purchase intention. This literature review focuses on the following issues: social media influencer marketing; credibility, expertise and attractiveness; Generation Z purchase intention; and influencer credibility and purchase intention.

2.1 *Social media and influencer marketing*

The interaction through social media platforms enables consumers, influencers, and brands to communicate with each other. As per Kaplan and Haenlein [1], social media are Web 2.0 applications that allow generating user-generated content and engaging in two-way interactions. In contrast to conventional advertising, where consumers did not have direct communication with brands, social media allows consumers to communicate with brands directly.

Influencer marketing is becoming one of the most successful digital marketing strategies via platforms including Instagram, TikTok, YouTube, and Facebook. According to Brown and Hayes [2], influencer marketing means using individuals capable of influencing consumer opinions and decisions. Being authentic and relatable, influencers form a strong relationship with their followers. Freberg et al. [3] suggested that influencers were considered knowledgeable, trustworthy, and approachable; hence, their recommendations were credible

2.2 *Generation Z as digital consumers*

Generation Z refers to people who have grown up in a digital world and are connected through technology and social media. Generation Z makes decisions through online reviews, digital content, and influencer recommendations. Generation Z prefers interactive and personalised communication over promotional ones.

According to Priporas, Stylos, and Fotiadis [4], Generation Z focuses on convenient experiences and instant information access, facilitated by technology. In relation to the fact that Generation Z is constantly involved in social media, influencers are vital in providing product information during the buying process. Influencer recommendations are usually considered to be trustworthy since it seems like an experience.

2.3 *Influencer credibility and purchase intention*

The credibility of influencers is one of the most important determinants for the success of influencer marketing. These are mostly determined by means of expertise, trustworthiness, and attractiveness. Expertise is about an influencer’s awareness of a particular product, trustworthiness is about being honest and reliable, and attractiveness involves personality.

According to Lou and Yuan [5], influencer credibility positively affects consumer trust and purchase intentions. It can be said that consumers are more willing to purchase products endorsed by credible influencers. Influencers’ credibility lowers consumer uncertainties and increases consumer confidence when buying something.

2.4 *Credibility, expertise and attractiveness*

Based on the source-credibility perspective in influencer marketing research, this study examines credibility, expertise and attrac-

tiveness as distinct but related dimensions of how consumers evaluate an influencer. Credibility refers to the extent to which an influencer is perceived as honest, unbiased and believable when endorsing a product [6]. Expertise concerns the influencer's perceived knowledge, skills and experience with the product category being promoted. Attractiveness extends beyond physical appearance to include personality, creativity and overall appeal of an influencer's content and communication style [6],[7]. Trust-related qualities such as honesty and reliability are commonly treated as a core part of credibility rather than as a wholly separate construct [7], and this study follows that convention: items capturing trustworthiness were incorporated into the credibility measure rather than analysed as an independent variable. Sokolova and Kefi [7] found that credibility and parasocial interaction jointly shape purchase intention on Instagram and YouTube, while Alfarraj et al. [6] showed that attractiveness and expertise both influence purchase intention indirectly through consumer engagement. These findings support treating the three attributes as related but empirically distinguishable predictors of purchase intention.

2.5 *Similar Studies*

Recent studies have identified the influencer-consumer relationship in numerous settings. Bu, Pakinson and Thaichon [8] found that perceived homophily with an influencer strengthens value co-creation behaviour and purchase intention among younger consumers. Cabeza-Ramírez et al. [9] reported that perceived trustworthiness lowers perceived purchase risk and increases product involvement, while Gosh et.al [10] showed that influencer credibility and engagement jointly shape Generation Z's behavioural intentions in the food and beverage sections. A meta-analysis by Han and Balabanis [11] synthesised antecedents of social media influencer impact across dozens of studies and confirmed that credibility-related attributes are consistently among the strongest predictors of downstream consumer outcomes such as purchase intention. Boerman [12] demonstrated that clear disclosure of sponsored content does not necessarily undermine trust when the influencer is otherwise perceived as authentic. Gohil et al. [12] further found that authenticity operates largely through trust and perceived credibility rather than as an independent driver of purchase intention, a pattern this study also aims to examine. Cintamur [14] demonstrated that influencer credibility continues to shape Generation Z's purchase intention and word of mouth even after brand attitude is accounted for.

2.6 *Research gap and summary*

While previous studies have researched influencer marketing and purchase intention separately, little research has been done with Generation Z consumers in Sri Lanka. Due to cultural differences, societal values, economic conditions, and digital literacy, consumers might behave differently than those in other countries. Thus, the aim of this study will be to examine the effects of influencer marketing on social media on the purchase intentions of Generation Z consumers in Sri Lanka. It is known from the literature review that credibility, expertise, trustworthiness, and authenticity of influencers significantly affect purchase intention. Accordingly, the hypotheses built from the study are;

H1. Influencer credibility has a significant positive effect on the purchase intention of Generation Z consumers in Sri Lanka.

H2. Influencer expertise has a significant positive effect on the purchase intention of Generation Z consumers in Sri Lanka.

H3. Influencer attractiveness has a significant positive effect on the purchase intention of Generation Z consumers in Sri Lanka.

3 METHODOLOGY

A quantitative research methodology was adopted to analyse the influence of social media influencers on the purchasing intention of Generation Z consumers in Sri Lanka. This approach was chosen as it would be able to gather numerical data from a large sample size of respondents and enable statistical analysis of data to identify relationships between variables. The study focused on measuring the effect of credibility and expertise, attractiveness and trustworthiness of influencers on the purchase intention of consumers.

The research design used was descriptive and explanatory. The descriptive part aimed

to gain insight into the demographic characteristics and social media usage patterns of the Generation Z consumers, and the explanatory part aimed to understand the impact of various types of influencer characteristics on purchasing behaviour. The study used a cross-sectional survey design that collected data at one time.

The target group was Generation Z people in Sri Lanka born between 1997 and 2012. The study employed a non-probability convenience sampling technique since it was easy for the researcher to get the respondents using Google Forms and collect data and analyse from Microsoft Excel for preliminary coding. The number of respondents obtained was valid respondents which is sufficient for descriptive and inferential statistical analysis in social science research.

A structured online questionnaire was used to gather primary data, which was created with Google Forms. There were two primary sections to the questionnaire. The first section collected information about the demographic, such as age, gender, education level, district, employment status, monthly income, preferred social media platforms, how many hours per day respondents utilise social media, whether they follow influencers and how often they were exposed to their posts and promotions. The second section asked respondents about their perceptions of influencer credibility, their expertise, attractiveness, trustworthiness, and purchase intent.

The questionnaire contained 33 variables, with 31 of them measured by a Likert scale that ranged from 1 = Strongly Disagree to 5 = Strongly Agree. This scale was selected because of the ease of investigating respondents' attitudes and perceptions in a way that is quantitative. The items used for measurement were adapted from previous literature to guarantee the content validity of the items used.

Data were gathered and then downloaded into the spreadsheet program, Microsoft Excel, for data cleaning and preliminary coding. The data set was reviewed for missing data, duplicate data and inconsistencies. Only completed questionnaires were included in the final sample of respondents.

The cleaned data were analysed in Microsoft Excel using descriptive statistics to summarise and interpret the data. Demographic characteristics of the respondents and their behaviour with social media were summarised using descriptive statistics such as frequencies, percentages, means and standard deviations. Correlation analysis and multiple regression analysis were used in this study to evaluate the relationships between the influencer characteristics and the purchase intention. The strength and direction of relationships between variables were assessed through correlation analysis, and the amount of predictability of purchase intention was determined through multiple regression, which examined how well the influencer's credibility, expertise, attractiveness, and trustworthiness could predict the intention of Generation Z consumers to make purchases.

In order to guarantee the quality of the measurement instrument, reliability analysis was done by means of Cronbach's Alpha. Cronbach's Alpha was used to determine the internal consistency between the items of the questionnaire, and values above 0.70 were deemed acceptable. Additionally, the questionnaire was developed using previously used and validated scales of measurement to increase construct validity. In the correlation and regression analyses, the significance level was set at less than 0.05.

Ethical issues were adhered to during the research. No one was forced to participate, and those people who took part in the study were told what the study was about before filling in the questionnaire. No personally identifiable information was gathered; thus, respondents' data were anonymous and kept confidential. It was also explained to the participants that they could leave the survey at any point without repercussions. The data collected was used only for academic purposes and was kept securely to ensure that respondents' privacy was protected.

Overall, this methodology was found to be systematic and reliable in investigating the influence of social media influencers on the buying behaviour of Generation Z consumers in Sri Lanka. Structured questionnaires, standardised measurement scales and statistical analysis were used to ensure the findings were objective, reliable and applicable to the research aims and hypotheses.

4 DATA ANALYSIS AND FINDINGS

A total of 100 Generation Z respondents in Sri Lanka were selected for analysis to understand the effect of social media influenc-

ers on consumers' purchase intention. The data collection was conducted using a structured online questionnaire, and the data were analysed using descriptive statistics, correlation analysis and multiple regression analysis. The demographic characteristics, social media use habits and attitudes toward influencer credibility, expertise, attractiveness and purchase intention of respondents are discussed below. The outcomes provide insights into the effects of influencer marketing on Generation Z consumers' buying behaviour. The table below presents the demographic data as follows.

Table 1. Demographic profile of respondents (n=100)

Category	Sub-group	n	%
Age	14-17	19	19.2
	18-21	26	26.3
	22-25	50	50.5
	26-29	4	4.0
Gender	Male	27	37.4
	Female	62	62.6
Education	Below Ordinary Level	3	3.0
	G.C.E Ordinary Level	17	17.2
	G.C.E Advanced Level	14	14.1
	Diploma	6	6.1
	Undergraduate	52	52.5
	Postgraduate	7	7.1
Employment	Unemployed/ Full-time student	51	51.5
	Employed/Intern/ Self-employed/Part-time	48	48.5

The demographic profile confirms that respondents are an appropriate representation of the target population: Generation Z Sri Lankan consumers. The distribution shows that the majority of participants are part of the younger Generation Z, who are more interested in social media and content produced by influencers. As far as gender is concerned, a higher proportion of female respondents may be due to higher engagement in social media platforms or higher motivational level towards influencer-related content; hence, interpretation of results should be made with caution as purchasing behaviour can be different between genders. Education indicates that the typical profile of Generation Z is in the higher education learning phase. With regard to employment status, the comparable percentage said they did not have any personal income, a common occurrence for a student-dominated sample. These respondents are still important consumers who can influence household buying decisions, even without a steady income, and can be seen as future consumers with purchasing power.

4.1 *Social media usage*

The findings suggest that Gen Z is extremely active social media users. Most people (79%) reported using social media for 3 to 4 hours a day; a significant portion (22%) reported using social media more than four hours a day, while a small minority of respondents (9%) reported using social media less than an hour per day. Digital engagement is so high that exposure to influencer-created content and online marketing becomes that much. The survey also found that nine out of ten respondents follow social media influencers and one out of ten does not. As demonstrated, influencers are an important source of information and entertainment for Generation Z consumers. Furthermore, many respondents also reported seeing influencer promotions on social media quite frequently, indicating that influencer promotions have become an integrated part of their own social media experience and as part of their own purchasing journey. Overall, the perception of credibility amongst respondents was rather conservative, with average scores for items relating to credibility being below the mid-point of the scale, indicating Generation Z consumers in this sample are not automatically accepting of content from an influencer and tend to assess credibility before forming an opinion. Despite this, there was a clear correlation between credibility and purchase intention of the influencers, and the higher the credibility of the influencers, the more likely people were to indicate that they intended to purchase a product the influencers like. The table below represents the data likewise.

Table 2. Reliability of the measurement scales

Construct	No. of Items	Cronbach's Alpha
Credibility	6	.81
Expertise	5	.78
Attractiveness	5	.83
Purchase Intention	5	.85

Moreover, attitudes toward influencer expertise were more positive than credibility, with those who see influencers as having a true understanding of the products, as explaining

how the products work and work best in a clear way and as having true product experience being considered more credible sources of information. On a self-explanatory basis, expertise was related in a positive direction with purchase intention. When viewed in tandem alongside credibility and attractiveness, however, expertise was not seen to have a distinct independent effect, and its influence seems to be highly intertwined with that of credibility as perceived by a consumer, suggesting that Generation Z consumers may not be able to distinguish between an influencer's product knowledge and their level of credibility.

Table 3. Descriptive statistics of constructs

Construct	Mean	SD
Credibility	2.86	0.61
Expertise	3.42	0.58
Attractiveness	3.58	0.64
Purchase Intention	2.93	0.66

The above table shows credibility and purchase intention were both rated just below the scale of mid-point, whereas expertise and attractiveness were rated more positively, a consistent pattern observed in the discussion.

4.2 *Analysis of influencer attractiveness*

In this sense, attractiveness can be more than just a physical quality: it's about the influencer's personality, communication, creativity and overall attractiveness. Overall, the participants stated that content developed by influencers whose appearance or personality they find appealing or attractive is interesting and fun to watch, and that it is more interesting to follow the content of such influencers than it is to follow the content of others.

This sample's attractiveness was not only not a weak or secondary factor affecting purchase intention, but it was clearly and meaningfully associated with purchase intention, placing it second only to credibility, as is sometimes assumed in influencer marketing research. It indicates that an influencer's influence and image are more influential on the purchase intention of this group of Gen Z consumers than is widely believed, not just in getting their attention, but in making them want to buy.

4.3 *Analysis of purchase intention*

Purchase intention is defined as individuals' desire to make a purchase of a product when they see an endorsement by a social media influencer. The average response for each purchase intention statement was also just below the scale midpoint, finding that Gen Z consumers in this sample clearly take influencer content into account when it comes to attitudes and consideration, but not quite all of them are excited to follow through with an influencer recommendation. The majority of the respondents said that they would seek additional info about a product after seeing an influencer recommendation, compare alternatives and consider buying the product they recommended, though not right away. It is evident that influencers can be relevant in various parts of the consumer decision-making process, even if it doesn't necessarily result in an instant conversion.

4.4 *Overall findings*

Overall, the findings indicate that both the credibility and attractiveness of the influencers have a statistically significant positive impact on the purchase intention of Generation Z consumers in Sri Lanka, where the former has the highest positive correlation, followed by the latter. When used individually, influencer expertise was positively associated with purchase intention, but not when credibility and attractiveness were considered, probably because the expertise of an influencer often goes together with its credibility.

Table 4. Pearson correlations among variables

Variable	1	2	3	4
Credibility	-			
Expertise	*.52*	-		
Attractiveness	*.41*	*.38*	-	
Purchase Intention	*.58*	*.35*	*.49*	-

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

Table 5. Multiple regression predicting purchase intention

Predictor	B	SE	β	t	Sig.
(constant)	.81	.22		3.68	.000
Credibility	.39	.09	.42	4.33	.000
Expertise	.07	.08	.08	0.88	.381
Attractiveness	.28	.10	.27	2.80	.006

$R^2 = .41$, Adjusted $R^2 = .39$, $F(3, 95) = 21.87$, $p < .001$.

Table 6. Summary of hypotheses testing

Hypothesis	β, Sig.	Decision
H1: Credibility → PI (+)	β=.42, p<.001	Supported
H2: Expertise → PI (+)	β=.08, p=.381	Not supported
H3: Attractiveness → PI (+)	β=.27, p=.006	Supported

These results suggest that the Generation Z consumers in this sample group make purchase decisions based on the influencer's perceived trustworthiness and honesty, as well as the perceived engagement and appeal of their content and persona, more so than perceived expertise and popularity of the product. This shows that these digital consumers are now at a more advanced stage in their decision-making process around influencer marketing; they are more interested in authenticity and relatability than superficial credentials.

The findings from the data collected from 99 Generation Z respondents in Sri Lanka on the impact of social media influencers on purchase intention were analysed in this chapter. As for demographics, the respondents were regular social media users and engaged with content of influencers often. Credibility and attractiveness were significant and positively related to purchase intention, with expertise not being a significant independent predictor of purchase intention after the other two attributes were added. The findings from these will be used in the preceding sections.

5 DISCUSSION

The purpose of this study was to explore the impact of social media influencers on the buying behaviour of Generation Z consumers in Sri Lanka. The findings indicated that social media influencers do have an impact on consumers' purchase intention, and that both influencer credibility and influencer attractiveness have positive correlations with purchase intention. Of these two factors, credibility was the better predictor; attractiveness was the next. When credibility and attractiveness were controlled for, expertise did not emerge as an independent predictor but was related to purchase intention alone. The findings of these are of great value in understanding the responsiveness of Generation Z consumers to the content created by influencers in the digital marketplace in Sri Lanka, and how this content influences their purchases.

This finding is the most critical for this study: purchase intention is most affected by the credibility of the influencers. Generation Z consumers seem to appreciate the authenticity, transparency, and honesty of influencers in presenting products. This implies that consumers are more likely to accept suggestions of a product when they think that the influencer is recommending the product due to their belief in it, not just for monetary reasons. Users' growing awareness of sponsored content and paid partnerships on social networks makes trustworthiness and authenticity essential to consumer trust. Earning trust and credibility is more likely to happen with influencers who are consistent, transparent, and open with their audience about their own beliefs and knowledge of the product.

Another meaningful influence on purchase intent in this study, and second strongest, was attractiveness; this is not the first time attractiveness has made the grade in an influencer marketing study, despite being thought of as the weakest of the bunch. The outcomes from this study indicate that attractive influencers are able to attract attention and initiate engagement on social platforms and that the personality, presentation and overall appeal of an influencer also have a significant impact on the willingness of Generation Z consumers from Sri Lanka to consider an item they are recommended to purchase. This means that in this market, likeability and engaging content are more important than is usually thought.

Interestingly, the presence of an independent relationship between purchase intention and influencer expertise is not apparent when credibility and attractiveness are controlled, even though the presence of this relationship is present when credibility and attractiveness are not controlled. However, this does not mean that expertise is not important to consumers (many of the respondents did value influencers who showed genuine knowledge and experience of the product); rather, its influence is to be seen to be through, or to run parallel to, how credible the influencer is perceived to be by consumers. Put another way, Generation Z consumers may not be able to tell the difference between an influencer's product expertise and their authenticity and credibility, and often they will assume the two are the same

when the influencer appears credible. It implies that expertise is not a separate feature from credibility, but rather something to support its credibility.

In addition, the results reveal that Gen Z consumers spend a considerable amount of time on social media platforms like Instagram, TikTok, YouTube, and Facebook, and are regularly consuming content created by influencers. This frequent touchpoint offers brands a chance to reach potential customers repeatedly via influencer marketing campaigns, and continues to emphasise that influencer marketing is a standard way of finding and assessing products for Generation Z.

The results of this study also provide practical implications for businesses and marketers. For Generation Z consumers, companies should look for influencers who are credible and are engaging and relatable, rather than just influencers who have a product message. Even if the influencer has fewer followers but is more authentic and honest, it may be more advantageous to work with them than with an influencer who, while popular, claims to be an expert. Brands should also urge influencers to create authentic content, label sponsored content, and provide an honest opinion of the brands they promote, as these factors seem to resonate best with Gen Z's purchasing decisions.

In general, the findings indicate that influencer marketing is indeed a strong tool for influencing the purchasing decisions of Gen Z consumers in Sri Lanka, where credibility and attractiveness are the key influencers and authenticity is more significant than expertise and popularity alone. To maximise the impact of their influencer marketing campaigns, brands should prioritise cultivating relationships with trusted, relatable influencers who can connect with their Gen Z target audiences on a real level and prompt positive product purchases.

6 CONCLUSION

The research aimed to explore the impact of social media influencer marketing on the purchase intention of Generation Z in Sri Lanka. Given the fast-growing trend in digital marketing, influencer marketing has emerged as an important means of communication and product promotion for organisations. Three influencer attributes: credibility, expertise, and attractiveness were analysed in the study. The results indicate that both credibility and attractiveness positively and significantly influence the purchase intention of Generation Z consumers, with credibility being the most influential factor followed by attractiveness. When examined individually, influencer expertise was related to intention to purchase, but not when credibility and attractiveness were taken into consideration. It has been determined that Generation Z values honesty, transparency, and engagement of an influencer more than their knowledge of the product and popularity. While skill did not prove to be a standalone predictor in this study, it is certainly a salient feature to consumers' notice and appreciation, and its effect seems to come through, not as a separate factor from credibility. This implies that consumers don't split honesty and knowledge up into distinct categories, and brands need to consider them as one, not two.

7 RECOMMENDATIONS

Based on the research findings, apart from the number of followers, businesses should base trust and credibility on other factors when selecting influencers. Before a partnership, companies need to evaluate an influencer's track record, whether their engagement is authentic and whether the reputation is positive. Finally, it's important for a brand to consider the personality and presentation style of the influencer, as this study revealed that this can significantly influence purchase intent, irrespective of whether it gained initial interest. Although matching the influencer's expertise with a suitable product category is a reasonable practice for perceived relevance, this study indicates that perceived expertise does not seem to be a separate determining factor, but rather the perceived credibility of the influencer. Thus, brands should focus on influencers who appear to be knowledgeable and honest when used in combination and not just in isolation. Lastly, it is crucial to encourage influencers to create genuine content, such as personal experiences, demonstrations, and honest reviews, while also ensuring that they clearly label sponsored content to maintain consumer trust. Partnering with micro-influencers is also a good

idea since they tend to have a more intimate and active relationship with their followers.

8 LIMITATIONS

The study has some limitations. The sample size was relatively small, consisting of 99 valid respondents from Generation Z in Sri Lanka, which may limit the generalisability of the results and suggests that future studies could benefit from larger samples. Secondly, the convenience sampling method may have introduced sampling bias, as respondents were selected for convenience rather than systematically. Moreover, a cross-sectional research design was used, and the information was recorded only at one point in time; social media trends and consumer preferences can change rapidly. Also, trustworthiness was not measured as a separate construct in this study; related components (such as honesty and reliability) were incorporated into the credibility measure rather than measured separately, which may account for some of the overlap between credibility and expertise. Further research should assess trustworthiness separately to gain a clearer picture of its role. Lastly, some other attributes of influencers were not investigated in the current study and may merit further investigation in future studies, for example, authenticity, content style, and electronic word-of-mouth.

9 SUGGESTIONS FOR FUTURE RESEARCH

Future researchers can use larger and more diverse samples from other parts of Sri Lanka for this study. Researchers might also compare Generation Z individuals with individuals from other generations to know the differences in the effectiveness of influencer marketing.

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Predictive Modelling for Leading Cryptocurrency Prices with Structural Changes

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ABSTRACT: Cryptocurrency markets are very unstable. Thus, fitting a reliable price forecasting model is a real challenge. This study provides a comprehensive analysis of predictive models while incorporating structural change detection. Daily data of the most demanding cryptocurrencies, namely Bitcoin, Ethereum, Binance Coin, and Ripple, from 2021 to 2025 were analyzed, fitting both univariate and multivariate time series approaches. Multivariate Changepoint Detection was applied to identify significant changepoints in the entire series. Again, models were fitted in each segment. Then, the results indicate that models derived from structural breaks provide more reliable forecasting accuracy, highlighting the value of capturing regime shifts in financial time series modeling. Segment-based models such as Random Walk, VAR(1), AR(3), and regression models produced lower RMSE values under recent market conditions. By adding blockchain-based indicators as exogenous variables into the selected better-performing models, future research will be able to enhance prediction accuracy.

Keywords: Cryptocurrency Forecasting, Multivariate Changepoint Detection, Time Series Models, Vector Autoregression, Bitcoin

1 INTRODUCTION

In ancient times, people used barter systems where goods were exchanged directly. Later, this shifted to physical coins and currency notes, which we use nowadays. With the advancement of technology, cryptocurrency is becoming a vital component in modern transactions. It is a virtual coin that uses blockchain technology and works without a central authority. Rupees and USD are issued by central banks, whereas cryptos are generated through decentralized computational processes known as mining. In the past, two to four weeks were spent exchanging money between countries. In 2009, Satoshi Nakamoto launched the first crypto coin, Bitcoin, as a solution to that [1]. With the rapid growth of technology and the evolution of the financial system, the crypto market, which is like the stock market (buying & selling), has created significant interest among investors, financial analysts, and policymakers. After the incident in 2010, Bitcoin Pizza Day, where a person purchased two pizzas for 10,000 BTC [2], crypto trading became a popular online income source, especially among the youth.

However, it is very risky because markets are influenced by many hidden factors such as news, rules, social media, political conflicts, macroeconomic factors, network activities, and investor behavior. Therefore, a lack of regulation and emotional trading can lead to poor decisions. Cryptocurrency forecasting is challenging because not only day-to-day, but also minute-to-minute prices are changing. Since external factors result in structural breaks in prices, researchers try to build predictive models by identifying these regime shifts, known as changepoints. The novelty of this analysis is to develop and

compare widely used time series models by detecting structural market changes to improve forecasting accuracy. This study provides a comprehensive comparison of major cryptocurrencies. The findings will be useful to support investors in applying more effective trading strategies and future researchers in predicting models for highly volatile financial series.

2 LITERATURE REVIEW

In some past research papers, classical models such as ARIMA were fitted to capture linear temporal dependencies in crypto price series [3], while GARCH models were used for volatility modelling [4]. These approaches provide strong theoretical interpretability. With the development of artificial intelligence, many recent studies have applied machine learning models and deep learning models such as LSTM, GRU, and hybrid CNN-LSTM [5]-[8], focusing more on predictive performance. Only a few contexts have explored the effect of blockchain indicators like transaction volume and market capitalization on price data for enhancing the accuracy of the models [9], but the inclusion of such exogenous variables increases model complexity. In South Asia, research has primarily focused on price prediction, with India leading many studies [2],[5],[10],[11]. Studies in Sri Lanka have focused on crypto trading adoption, investment behavior, and basic price prediction on a single coin [12]-[15]. However, this study addresses the gap in comparative analysis for multiple cryptocurrencies with the Multivariate Changepoint Detection (MCPD) method.

3 METHODOLOGY

3.1 *Data Selection & Preliminary Analysis*

Based on the trading industry and related works, Bitcoin (BTC), Ethereum (ETH), Binance Coin (BNB), and Ripple (XRP) were selected as top cryptocurrencies [10]. The dataset was collected from the CoinMarketCap website and contains daily closing prices of the above coins from 1st January 2021 to 14th September 2025, covering 1718 days, reflecting their demand in the market [16].

There were no missing values, but some true outliers reflecting actual market behavior were present. Initially, the time series plots for the original series were visualized, then stationarity was assessed using KPSS, ADF, and PP tests [17]. After applying log transformation and differencing, the dataset was divided into training (80%) and testing sets (20%).

3.2 *Model Building for the Entire Series*

After identifying ACF and PACF cutoff lags, univariate candidate models (ARIMA, GBM) were built for each coin using the training set. Then, the validity of the assumptions, including normality, autocorrelation, and heteroscedasticity of residuals, was checked for the better models obtained using minimum AICs. Performance evaluations of fitted models were done by using RMSE values. Cross-correlation analysis and the Granger Causality test were applied to the entire returns series [18]. Then, using the Johansen Trace test (cointegration analysis) and optimal lag length selection criteria (AIC, HQ, SC, FPE), a multivariate time series model (VECM) was fitted. After model adequacy checking, structural analysis was conducted, including the Impulse Response Function (IRF) and Forecast Error Variance Decomposition (FEVD). Again, the performance was evaluated between forecasted values and the testing set.

3.3 *Multivariate Changepoint Detection Method (MCPD)*

A single time series model may not be accurate due to the highly volatile nature of the crypto market. Therefore, the changepoint detection method can be employed to capture the regime shifts in price series. Instead of identifying coin-specific market changes, the MCPD method is used to detect common structural breaks affecting multiple coins simultaneously. The nonparametric changepoint detection method, which is called E-Divisive, is used for the return series. This method is more suitable for cryptocurrency data, since the method is not based on strict distributional assumptions [19], [20]. This method can identify changes in mean, variance, or both. Then, relevant segments were derived using detected significant changepoints.

Next, as in the previous section, univariate models (ARMA, Exponential Smoothing, Random Walk, White Noise) and multivariate time series models (VAR) were built for each coin in each segment. In addition, regression models were derived by using only significant coefficients from VAR models separately for each coin in each segment. Then predicted for the test set after the models were diagnosed.

4 RESULTS & DISCUSSION

This section presents the key results based on the above methodology, including plots and performance evaluation. All statistical analyses were conducted using R statistical software (version 4.3.1).

Figure 1 indicates clear non-stationarity, as the mean levels vary over time and the variabilities are not stable. This suggests the presence of trends and structural movements in price data. Stationarity was achieved by taking the first difference of logarithmic prices for all four series. These return series were analyzed throughout this research, as is widely used in financial studies.

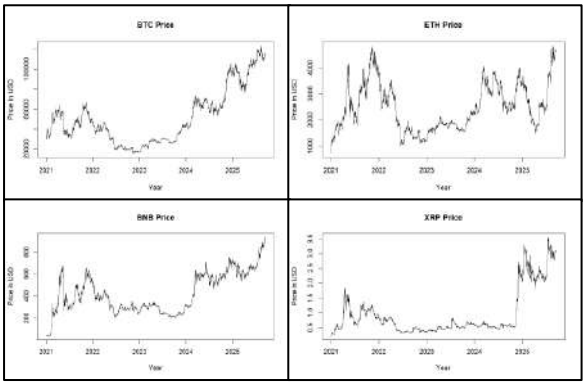


Figure 1. Time series visualizations for original series

First, for the entire series, coin-wise univariate models were fitted. The second column of Table 1 shows that these models (ARIMA) include too many lags, indicating model complexity. Furthermore, all the assumptions mentioned above were violated, except for autocorrelation.

Table 1. Better candidate models for entire series with RMSE values

Coin	Univariate Model with RMSE	Multivariate Model- VECM(9) with RMSE
BTC	ARIMA(8,1,9) | 0.46 GBM | 0.023	0.0234
ETH	ARIMA(8,1,8) | 0.32 GBM | 0.039	0.0393
BNB	ARIMA(9,1,10) | 0.21 GBM | 0.027	0.0245
XRP	ARIMA(2,1,2) | 1.44 GBM | 0.052	0.0508

Figure 2 represents the cross-correlation analysis and Granger causality between the entire return series. All the coefficients are greater than 0.5, indicating strong positive correlations. Darker red cells support rejecting the null hypothesis that X does not Granger-cause Y, where X is the cause and Y is the effect, at the five percent significance level.

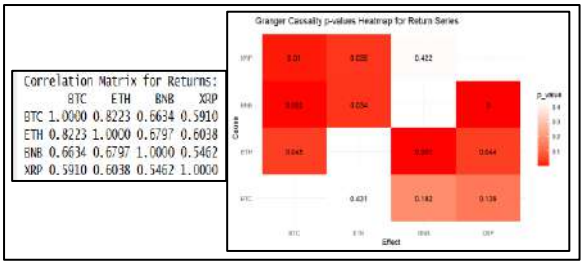


Figure 2. Cross correlation matrix & heatmap for Granger causality test

The rejection of all null hypotheses in the Johansen Trace Test suggests the presence of three significant long-run relationships among the cryptocurrency price series. Then, using the optimal lag length (AIC-10, HQ-1, SC-1, FPE-10), VECM(9) was fitted. But all the p-values of the Portmanteau (Serial Correlation), JB (Normality), and ARCH LM (Heteroscedasticity) tests are smaller than 0.05, indicating a violation of the assumptions. RMSE values of the VECM(9) model are in the third column of Table 1. Again, this is a less practical model due to the higher number of parameters.

Next, used the MCPD method to detect the change points.

Figure 3 emphasizes four statistically significant changepoints (five segments) detected at the dates 02/07/2021, 25/11/2022, 06/11/2024, and 08/12/2024 with p-values

of 0.002, 0.004, 0.012, and 0.034, respectively.

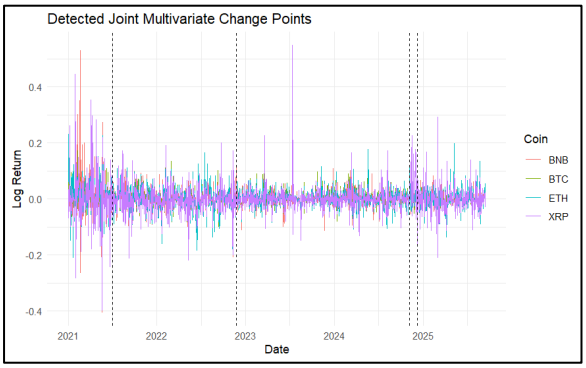


Figure 3. Plot for multivariate changepoint detection

Table 2. Summary of the segments

Window No. & Date Range	Total Data Points	Training (0.9) Set	Testing (0.1) Set
1: 02/01/2021 - 02/07/2021	182	163	19
2: 03/07/2021 - 25/11/2022	511	459	52
3: 26/11/2022 - 06/11/2024	712	640	72
4: 07/11/2024 - 08/12/2024	32	28	4
5: 09/12/2024 - 14/09/2025	280	252	28

Since there are only 32 data points in the fourth segment (Table 2), simple exponential smoothing and random walks were fitted. Market reasons behind these structural shifts were, respectively, the DeFi crisis due to the Iron Finance collapse - causing market panic and price drops; the crypto market downturn (crypto winter) driven by major failures like FTX and Terra/LUNA, macroeconomic changes, and increased institutional involvement, and a year-end market correction with profit-taking and temporary price declines.

Then, segment-wise univariate models were fitted for each coin. Residuals of all the models in Table 3 did not exhibit autocorrelation since they were derived from return series which were already stationary. After that, multicollinearity was checked to fit the segment-wise multivariate models.

Table 3. Candidate univariate models for each coin in each segment with RMSE values

Segment | Coin	Model	RMSE
Segment 1 | BTC	Exp.smoothing	0.048
	Random Walk	0.113
	Auto.arima - AR(1)	0.048
Segment 1 | ETH	ARMA(6,8)	0.069
	Auto.arima - ARMA(2,1)	0.063
Segment 1 | BNB	ARMA(2,10)	0.082
	Auto.arima – White Noise	0.073
Segment 1 | XRP	Exp.smoothing	0.084
	Random Walk	0.1096
	Auto.arima - White Noise	0.082
Segment 2 | BTC	ARMA(9,9)	0.034
	Auto.arima – White Noise	0.034
Segment 2 | ETH	Exp.smoothing	0.05
	Random Walk	0.0589
	Auto.arima - White Noise	0.05
Segment 2 | BNB	Exp.smoothing	0.044
	Random Walk	0.054
	Auto.arima - White Noise	0.044
Segment 2 | XRP	Exp.smoothing	0.053
	Random Walk	0.066
	Auto.arima - White Noise	0.053
Segment 3 | BTC	ARMA(8,8)	0.024
	Auto.arima – White Noise	0.023
Segment 3 | ETH	Exp.smoothing	0.031
	Random Walk	0.0399
	Auto.arima - White Noise	0.031
Segment 3 | BNB	ARMA(8,8)	0.022
	Auto.arima – White Noise	0.02
Segment 3 | XRP	ARMA(1,1)	0.025
	Auto.arima – MA(1)	0.025
Segment 5 | BTC	Exp.smoothing	0.0164
	Random Walk	0.0163
	Auto.arima - White Noise	0.0164
Segment 5 | ETH	Exp.smoothing	0.0408
	Random Walk	0.0415
	Auto.arima - ARIMA(2,1,3)	0.0407
Segment 5 | BNB	AR(8)	0.0239
	Auto.arima – AR(3)	0.0235
Segment 5 | XRP	Exp.smoothing	0.0314
	Random Walk	0.0317
	Auto.arima – AR(1)	0.0313

A VAR(1) model was fitted for each segment (except the fourth segment) using the optimal lag length (AIC-1, HQ-1, SC-1, FPE-1) because there were no long-run relationships among the price series. However, residuals have no autocorrelation; all roots exceeded 1, indicating stability, while nor-

mality and homoscedasticity were violated for these VAR(1) models. Since all the segments were sufficiently large (greater than 30 data points), asymptotically, everything was normal. Furthermore, the regression models were fitted using only the significant variables derived from the VAR(1) models for each segment. Finally, using the test sets, performance evaluation was done. Table 4 and Table 5 show the relevant RMSE values.

Table 4. RMSE values for multivariate models

Segment No. | Model	Coin	RMSE
1 | VAR(1)	BTC	0.0477
	ETH	0.0648
	BNB	0.0731
	XRP	0.0841
2 | VAR(1)	BTC	0.0338
	ETH	0.0500
	BNB	0.0436
	XRP	0.0532
3 | VAR(1)	BTC	0.0233
	ETH	0.0310
	BNB	0.0205
	XRP	0.0253
5 | VAR(1)	BTC	0.0164
	ETH	0.0407
	BNB	0.0236
	XRP	0.0313

Table 5. RMSE values for regression models of significant coefficients from VAR(1)

Segment No.	Regression Model	RMSE
1	ETH = XRP(lag1) .	0.0669
2	BTC = XRP(lag1) .	0.0340
	BNB = XRP(lag1) *	0.0449
3	BNB = BTC(lag1) ** +	0.0203
	ETH(lag1) .	0.0250
	XRP = XRP(lag1) ***	
5	ETH = BNB(lag1) *	0.0405
	XRP = BNB(lag1) . +	0.0345
	XRP(lag1) .	

Here ., *, ** and *** indicate 0.1, 0.05, 0.01, and 0.001 significance levels, respectively. These regression models have smaller R-squared values, but the residuals satisfied the assumptions. Based on the last regime shift (segment 5), the lowest RMSE values reported in Tables 3, 4, and 5 are obtained by Random Walk for BTC, a regression model for ETH, AR(3) for BNB, and VAR(1) for XRP.

5 CONCLUSION

Overall, this study emphasizes that utilizing MCPD and focusing on the recent market regime enhances forecasting accuracy compared to the models fitted on the entire dataset without identifying structural breaks. Furthermore, integrating blockchain-based indicators as exogenous variables in selected better-performing models of each cryptocurrency will lead to a decrease in predictive error in future research.

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Determinants of Customer Satisfaction in AI-Powered Banking Applications among Young Adults aged 18–35 in Sri Lanka

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ABSTRACT: The rapidly developing artificial intelligence-powered applications and technology has transformed the way we deliver customer service. However, customer expectations and perceived performances are factors that influence the acceptance of AI powered applications and technology. This research examined the determinants of customer satisfaction in AI-powered applications in banking sector in Sri Lanka. This research is conducted based on Expectations Confirmation Theory(ECT). This research addresses the critical gap in how customer satisfaction is impacted by the variables of expectations confirmation theory of banking artificial intelligence powered applications among the young adults aged 18-35, who are most receptive to technological innovations in digital banking services. A quantitative research approach was adopted. This study analyzed quantitative data collected from 384 respondents using a structured questionnaire. The data analyzed by Partial Least Squares Structural Equation Modeling. The findings indicated that perceived performance ,customer expectation significantly influence customer satisfaction, with confirmation of customer expectation playing a critical mediation role. It is expected that the expectations of customers would be fulfilled or exceeded to lead to higher satisfaction, and this will confirmed by the findings. Based on these findings, this research provides valuable guidance on how to progressively improve user satisfaction in banking artificial intelligence powered applications and help financial institutions strike a balance between technological innovation and user experience.

Keywords: Artificial intelligence-powered applications, banking sector, customer satisfaction, Expectation Confirmation Theory, Sri Lanka

1 INTRODUCTION

The rapid development of modern technology and the proliferation of big data have sparked global interest in artificial intelligence(AI). The banking sector is now the largest sector using artificial intelligence technology [1]. The introduction of self-service branch networks and online banking services has significantly increased the use of AI in this [1]. However, it is questionable whether AI-powered applications always lead to customer satisfaction. Identifying the key factors that influence customer satisfaction will guide the banking sector in meeting and exceeding customer expectations [2]. This study used ECT as the theoretical framework. According to this theory presented by [3], customer satisfaction is based on the comparison of customers' initial expectations with the actual service performance.

The work in the banking sector sees AI applications as a tool to provide a complete understanding of the integration of intelligence. This will lead to the way in which banking operations are shaped for tasks such as chatbots, CRM systems, fraud prevention, and personalization [4]. It is a virtual assistant

Banks' AI-powered applications have the potential to completely transform banking operations by providing automated customer support, fraud detection, and customized features [5]. Therefore, consumer satisfaction for trust ,privacy and security in banks is largely based on their attitudes towards AI and expectations about data.

[6] emphasizes that there is a research gap in the study of customer satisfaction in AI powered applications and technologies. Furthermore, it is necessary to investigate the customer satisfaction of other AI financial products, not just chatbots, and how customer satisfaction varies in different countries, for which there is a significant research gap [6]. The recent study by [1], conducted in Sri Lanka in 2024 emphasized that no research published so far has specifically investigated the application of AI in the banking sector in Sri Lanka. Taking these research gaps into account, the current research study attempts to identify determinants of customer satisfaction in AI-powered applications in banking sector in Sri Lanka as there is limited empirical research available on this topic. Accordingly, this study is designed around the following research questions.

What are the determinants of customer satisfaction in AI- powered applications in banking sector in Sri Lanka.

What is the impact of customer satisfaction in AI- powered applications in banking sector in Sri Lanka.

The results of this study revealed that perceived performance was the most influential factor on customer satisfaction, with both a direct effect and an indirect effect through confirmation of customer expectations. Furthermore, the indirect effect of customer expectations was not significant, and the relationship could not be mediated by confirmation of customer expectations. Thus, it is confirmed that customer satisfaction with AI-powered banking applications is not increased by fulfilling customer expectations, but by the applications actually delivering higher performance.

2 LITERATURE REVIEW

2.1 *Expectations confirmation theory*

The Expectancy Confirmation Theory , proposed by [3], is a model of consumer behaviour that helps explain and predict how customer satisfaction occurs. This theory states that a customer's satisfaction is based on the degree to which his or her expectations and the actual performance of the service match. If the service meets the customer's expectations, the customer is satisfied. If the service does not meet expectations, the customer is dissatisfied. According to [7], customer satisfaction is the result of the relationship between these expectations and actual experiences. [8] argued that ECT is used to analyze the difference between the customer's expectations before a transaction and his or her actual experience after the transaction. According to [3] study, customer satisfaction is determined by whether or not the post-usage experiences meet or exceed expectations after using the service. Positive confirmation helps to result in customer satisfaction and continuance.

2.2 *Customer Expectations*

Customer expectations are the expectations that a customer has about a product or service that he or she believes he or she will receive and will receive in a transaction [9] Customer satisfaction with AI technology in the banking sector is greatly influenced by customer expectations. According to [10], customer expectations are a representation of the customer's expectations about a product or service and describe the general performance levels. These expectations can vary between individuals. They can also change over time. In the past, "customers expected service companies to do what they are supposed to do[11]. Customers using digital banking services expect efficiency, reliability, personalized services, and problem solving through AI, and fulfilling these expectations increases customer satisfaction. Adding AI to the banking sector has created new opportunities [12].There is a direct relationship between customer satisfaction and customer expectations. This customer satisfaction is believed to be built on the service that the customer expects [13].

2.3 *Perceived performance*

Perceived performance is the consumer's feeling about products or services and how they evaluate their value and quality [14].According to ECT , customer satisfaction occurs when the perceived performance of a service meets or exceeds their expecta-

tions. This is particularly important in digital banking services, where AI components are rapidly transforming the user experience. In banking, perceived performance is the customer's perception of the application's ability to meet customer expectations, perform specific tasks accurately, solve problems, and provide personalized service [12]. Previous research has shown that Perceived Performance and Confirmation of customer expectation together influence the satisfaction and acceptance of AI-based services in digital banking [12]. For example, research has shown that when an AI powered application is highly intelligent, has human-like emotions, and responds to needs, customer satisfaction and the need to use the application increase [15].

2.4 *Confirmation of customer expectations*

Confirmation of customer expectations is defined as the degree to which a customer's pre-purchase expectations and the performance of a product or service as experienced after use match [16]. This is a cognitive process and is based on a comparison between pre-purchase expectations and actual post-use evaluations. In the field of technology, customer expectation confirmation is the degree to which a customer's expectations about a product or service are met by their actual experience of using it [17].The expectation confirmation process is the process by which customers test the performance of a product or service after receiving it and compare that performance with their prior expectations[16].Confirmation is simply the fulfilment of customer expectations. In the service industry, customer expectations are confirmed only when the service provider actually delivers the valuable services that the customer expects[18]. According to ECT, [19] stated that there is a strong positive relationship between customer expectations and subsequent expectation confirmation.

2.5 *Customer satisfaction*

Nowadays, customer satisfaction plays a very important role in the performance and growth of many companies [20]. The idea of analyzing whether the services or products received by the user are different from what they expected is called user satisfaction [21]. If the customer has an expectation of receiving high-quality products or services, customer will be happy if customer receives services or products that meet those expectations. This allows the company to identify the likes and dislikes of their customers [22].According to ECT, customer satisfaction is not only influenced by the actual quality of the product or service, but also by the extent to which it meets the customer's prior expectations [3]. This theory clearly states that when the customer's performance meets or exceeds his or her expectations, positive confirmation occurs and high customer satisfaction occurs[19]. In particular, customer satisfaction in technology-based services is strongly influenced by factors such as performance and expectation confirmation [6].

2.6 *Artificial intelligence powered applications in Banking sector*

Artificial intelligence powered applications are those that collect data from digital or physical sources, analyze it, learn from it, and apply that knowledge to solve consumer problems and complex issues. Artificial intelligence applications used in the banking sector are chatbots, mobile apps,robot bank,cash and cheque deposit kiosks, digital wallet and virtual cards[23].

3 METHODOLOGY

This research is conducted using a quantitative research approach [24] and follows a positivism paradigm [25]. This study uses a deductive approach to test the hypotheses [25].

Based on the theoretical framework and empirical studies, the following hypotheses are developed.

H1: There is an impact of customer expectations on customer satisfaction.

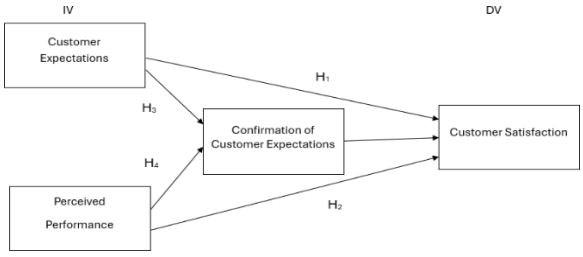


Figure 1. Conceptual model

H2: There is an impact of perceived performance on customer satisfaction

H3: Confirmation of customer expectations mediates the impact of customer expectation on customer satisfaction.

H4: Confirmation of customer expectations mediates the impact of perceived performance on customer satisfaction.

The population for this research is young adults between the ages of 18-35 in Sri Lanka. According to [26] sampling table ,the sample size of this study is 384.Here, a sample group is selected from the young adults aged 18-35 who use online banking services in Sri Lanka to collect data, and purposive sampling is used for this. For this study, primary data collection is done through questions, for which a structured questionnaire is used. To facilitate responses, data collection will be conducted through an online survey. The google form distributed via social media and emails. The questionnaire consists of demographic questions followed by 16 statements corresponding to the four variables, each rated on a five-point Likert scale.It collects from 23rd of July 2025 to 26th of August 2025.

4 DATA ANALYSIS AND RESULTS

In this research, descriptive statistics analysis and Partial Least Squares Structural Equation Modeling (PLS-SEM model) were used to analyze the data, which was implemented using Smart PLS software.The research questionnaire was distributed through google forms for data collection. Although the initial number of questionnaires collected was 396, since the sample size was 384, only that number was used for analysis as it met the regulatory criteria.

4.1 *Demographic analysis*

In the Questionnaire, it explain five demographic factors such as gender , age , highest education qualification , employment status ,geographical location. According to gender distribution, gender data from 384 respondents. 59.9% (230) of respondents were female and 40.1%(154) were male, indicating a higher female participation rate than males.The age distribution shows that the highest number of respondents is in the 25 - 30 age group, which is 62.5%(240). Respondents in the 18–24 age group are 18.49%(71), It is the lowest.According to highest education qualification distribution, the maximum group is the young population that undergraduates. It is 53.4%(205). According to the Employment status distribution, the highest percentage of 53.6% (206) is in full-time employment. Minimum 2.1% (8) answered that they are not in employment. According to the Geographical location distribution, the Southern Province represented the maximum part at 25.8% (99).The Sabaragamuwa Province has the lowest representation of 2.3% (9).

4.2 *Measurement model analysis*

The Measurement Model is used to assess whether the relevant concepts of the research are measured correctly. Based on the results obtained, Cronbach's Alpha, Reliability , Average Variance Extracted (AVE), and Fornell-Larcker Criterion were used to test reliability and validity.

4.2.1 *Reliability*

Outer loadings - Here, the factor loadings are examined. Since the indicator loadings in the outer loadings of this analysis exceed the minimum threshold of 0.7, this confirms the indicator reliability of the measurement model. Outer loadings values range from 0.797 to 0. 901.As per results, the threshold values for the four latent variables are greater than 0.7, indicating that all items reliably measure their constructs. This confirms indicator reliability [27].

Internal Consistency Reliability (Cronbach's alpha reliability) - Indicator reliability results indicate that the measurement model has a high level of internal consistency. As per table 1, Cronbach's alpha values for all constructs exceed the standard limit of 0.7. They range from 0.887 to 0.907. This confirms that there is strong internal consistency among the items in the respective construct [25].

4.2.2 *Validity*

Convergent validity - Since all Average variance extracted (AVE) values in table 1, exceed the minimum threshold of 0.5, it is a result that fully confirms convergent validity. These variables have high level of convergent validity.

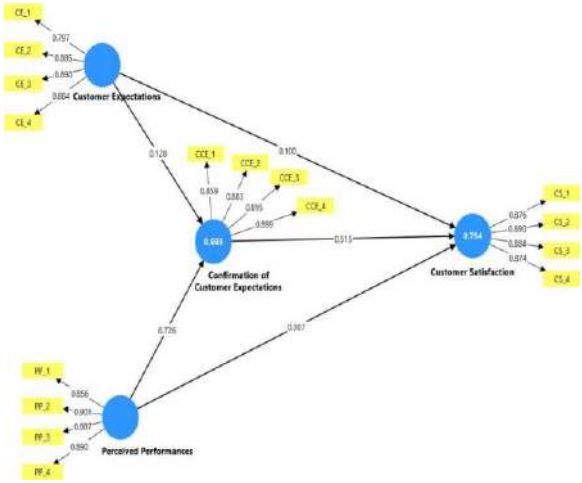


Figure 2. Structural equation model

Table 1. Construct reliability and validity

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Confirmation of Customer Expectations	0.907	0.909	0.935	0.782
Customer Expectations	0.887	0.892	0.922	0.748
Customer Satisfaction	0.904	0.909	0.933	0.776
Perceived Performances	0.906	0.908	0.934	0.781

Discriminant validity - Fornell-Larcker Criterion –According to the details of Table 2, each of the indicators here shows that the relationships with its indicators are stronger than the relationships with other indicators. That is, the diagonal values of the square root of AVE are greater than the correlations. Therefore, It can be ensured that there is good discriminant validity in this model[28].

Table 2. Discriminant validity - Fornell-Larcker criterion

	Confirmation of Customer Expectations	Customer Expectations	Customer Satisfaction	Perceived Performances
Confirmation of Customer Expectations	0.884			
Customer Expectations	0.710	0.865		
Customer Satisfaction	0.840	0.711	0.881	
Perceived Performances	0.829	0.801	0.814	0.884

4.3 *Structural model analysis*

This structural model is used to test the relationships between the constructs. The results allow us to evaluate how well the data supports the theory or concept.

4.3.1 *Quality criteria*

The results of the PLS-SEM analysis show that the model has strong explanatory power. According to table 3 Specifically, the predictive data explained 69.3% of the variance in customer engagement (R^2 = 0.693, Adjusted R^2 = 0.691) and 75.4% of the variance in customer satisfaction (R^2 = 0.754, Adjusted R^2 = 0.752). According to the guidelines for interpreting R^2 values in PLS-SEM, these results can be considered strong explanatory power

Table 3. R-squared

	R-square	R-square adjusted
Confirmation of Customer Expectations	0.693	0.691
Customer Satisfaction	0.754	0.752

4.3.2 *Model fit*

According to the Model Fit Index in table 4, it is shown that the model fits successfully. The SRMR value is obtained as 0.056, which is less than the recommended limit of 0.08, indicating a good fit. The d_ULS (0.427) and d_G (0.340) values are also low, confirming the model fit. The NFI value is obtained as 0.870, which has reached an acceptable level. Accordingly, it can be confirmed that the model fits perfectly.

Table 4. Model fit

	Saturated model	Estimated model
SRMR	0.056	0.056
d_ULS	0.427	0.427
d_G	0.340	0.340
Chi-square	735.845	735.845
NFI	0.870	0.870

4.3.3 *Path coefficient*

Table 5. Hypothesis test results

Hypothesis	Original sample (O)	Sample mean (M)	T statistics (|O/STDEV|)	P values	Result
H1: There is an impact of customer expectations on customer satisfaction.	0.1	0.1	2.258	0.024	Accept
H2: There is an impact of perceived performance on customer satisfaction.	0.307	0.306	4.998	0	Accept
H3: Confirmation of customer expectations mediates the impact of customer expectation on customer satisfaction.	0.066	0.067	1.845	0.065	Reject
H4: Confirmation of customer expectations mediates the impact of perceived performance on customer satisfaction.	0.374	0.374	6.624	0	Accept

Based on Table 5, the Hypothesis test was conducted using p-value. The results show that Customer Expectations have a significant positive effect on Customer Satisfaction. The Original Sample Value is 0.100, and the t-statistic value is 2.258. The p-value is 0.024, which is less than 0.05. Thus, the Hypothesis is accepted. Therefore, Hypothesis 1 is accepted, which means that customer expectations increase, which confirms that customer satisfaction also increases. Perceived Performance has a positive effect on Customer Satisfaction. The Original Sample Value is 0.307, and the t-statistic is 4.998. The p-value is 0.000, which is less than 0.05. Therefore, Hypothesis 2 is accepted, which means that when customers perceive that AI-powered banking applications are performing well, their satisfaction increases significantly.

4.3.4 *Mediator analysis*

Under H3, it was tested whether Confirmation of Customer Expectations mediates the relationship between Customer Expectations and Customer Satisfaction. The Original Sample Value is 0.066, and the t-statistic is 1.845. Here, the p-value is 0.065, which is greater than 0.05. Thus, the moderating effect is not significant. Therefore, Hypothesis 3 is rejected, indicating that Confirmation of Customer Expectations does not significantly mediate the relationship between Customer Expectations and Satisfaction. This means that customer expectations only has a direct impact on customer satisfaction.This can be identified as no mediation, because indirect path is not significant and direct path is significant only.

Under H4, it was analyzed whether Confirmation of Customer Expectations mediates the relationship between Perceived Performance and Customer Satisfaction. Here, the Original Sample Value is 0.374, and the t-statistic value is 6.624. The p-value is 0.000, which is less than 0.05. Thus, the mediate effect is significant. Therefore, Hypothesis 4 is accepted. This means that perceived performance not only directly affects customer satisfaction, but also has a positive effect through confirmation of customer expectations. This can be identified as partial mediation, because both the direct and in.direct paths are significant.

5 DISCUSSION

One of the findings of the above data analysis is that customer expectations have a direct positive effect on customer satisfaction with AI-powered banking applications(H1). This suggests that when customers start using AI powered applications, their customer satisfaction increases when they have positive expectations about features such as fast responses, helpful guidance, and easy navigation. This shows that banking institutions should not ignore customer expectations [18]. It is advisable to create user-friendly interfaces and proactively communicate about the capabilities of the application, especially during the design and onboarding phases. This will help to build customer expectations in a positive way. Recent studies have shown that dimensions such as reliabil-

ity, responsiveness, accessibility and security have a direct positive impact on satisfaction with AI powered banking services. .According to the results of this study, perceived performance has a strong and significant effect on customer satisfaction with AI-powered banking applications(H2).A key finding here is that customer judgments about whether AI powered application services operate efficiently and reliably are a key determinant of satisfaction. Specifically, factors such as speed, accuracy, reliability, and problem-solving ability in chatbots or mobile banking apps are revealed to be critical dimensions that directly increase satisfaction [18].This finding also aligns with a study by [6], which confirmed that perceived performance is one of the strongest predictors of customer satisfaction in digital banking contexts. These findings indicate that performance excellence is the main driver of happiness in AI-powered banking applications. This is often more powerful than customer expectations.

The findings of this research indicate that the mediation of Confirmation of Customer Expectations does not influence the relationship between customer expectation and customer satisfaction(H3). Customer expectation directly impacts customer satisfaction, but this effect remains unchanged by need validation. The main reason for rejecting H3 is that in the AI enabled banking application environment in Sri Lanka, younger generation customers depend more on direct perceived performance and post-experience confirmation does not have a significant impact. Furthermore, since the direct effect between Customer Expectations and Customer Satisfaction is strong, there is no space for a mediation effect . Also, since AI banking applications are a new technology, the actual experience of users reduces the variance in confirmation perception. Since young users are familiar with the technology, the direct impression of service performance does not require the mediation of confirmation. For these reasons, H3 may has been rejected. This aligns with the findings of [29], which indicated a direct relationship between customer expectation and customer satisfaction, with no mediation effect.Furthermore, a study by [6] in Turkey has revealed that customer expectations directly affect customer satisfaction, and that confirmation of customer expectations does not have a impact on customer satisfaction. Another finding from this study is that Perceived Performance has a strong mediating effect through confirmation of customer expectations. When AI-powered applications assistants operate with confidence and efficiency, customers are not only happy with that perceived performance, but also feel that their expectations have been confirmed. These results are also consistent with previous studies. The strong mediating role of confirmation of customer expectations in the relationship between and perceived performance and customer satisfaction is consistent with the ECM of information system.

6 CONCLUSION

The study considered the determinants of customer satisfaction on AI-powered banking applications in Sri Lanka. Initially, it is understood that AI has the potential to enhance services, yet there was not much knowledge of how precisely Sri Lankan users perceive these AI powered applications. A cross-sectional, meta-analysis was conducted among young adults aged 18–35 using a questionnaire based Expectation Confirmation Theory. The data obtained were analyzed using SmartPLS software. Confirmation of customer Expectation partially mediates this relationship. The study determined that customer expectation and perceived performance directly influence customer satisfaction, with perceived performance being met being the most significant factor. There are several limitations to this study that are not fully covered. First, since purposive sampling was used, the sample does not represent the entire target population, and therefore the results cannot be generalized to the entire population. More questions were raised, including how the long-term customers or older users perceive such services. Future studies need to test additional age groups, bring the research to other markets, and test the impact of AI personalization on customer satisfaction. Further research on personalization, security, and ease of use of AI applications is needed. Long-term changes in customer satisfaction with AI technology should be studied. The research sets the stage for enhancing AI-powered applications and technologies.research, which considers expectation confirmation as a primary driver of satisfaction [30]. The findings of this

study align with the empirical study of [31], which justifies the use of ECT alongside Self-Determination Theory to investigate mobile banking apps. [31] described that confirmation of customer expectation acts as a mediator for the relationship between perceived performance and customer satisfaction. The study found a mobile banking quality impact on confirmation as statistically significant which, in turn, influenced satisfaction. It is this partial mediation role that highlights the user's performance-based confirmation as a source of both satisfaction and continuance intention in digital banking scenarios, thereby constituting strong evidence for the current study's consideration of H4.

There are several limitations to this study that are not fully covered. First, since purposive sampling was used, the sample does not represent the entire target population. Second, AI powered application services are still in the early stages of their product life cycle, and the number of consumers who have experienced these services is limited. Third, since this research was conducted in a developing country with relatively medium technology sensitivity and a young population, the results may not be directly applicable to other countries. Recommendations for future research can be made from this. Researchers should include a broad perspective on AI-powered banking applications, including age groups and people with different education levels. For future research, it is important to collect data from different demographic groups, conduct longitudinal studies to monitor changes in customer satisfaction with AI technology, and further investigate specific AI functionalities and customer perspectives. Several implications for the banking industry, educational practices ,policy can be outlined from this study. It extends the research on AI adoption and customer loyalty in banking industry of Sri Lanka as well as provides evidence about how AI powered applications impact on customers satisfaction. From educational and policy perspectives, the results suggest that AI-based Fintech should be incorporated into business and IT programs and shape more customer-oriented AI solutions by policymakers as well as banks.

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The Impact of Scope Creep on the Success of Construction Projects in the Western Province of Sri Lanka

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ABSTRACT: In Today's construction industry, scope creep, defined as uncontrolled changes in project scope, remains one of the most critical challenges affecting project success. In the Sri Lankan context, particularly within the western province, construction projects play a vital role in economic growth, yet many suffer from cost overruns, delays, and compromised quality. While contractual clarity, stakeholder engagement, and organizational learning have each been linked to project success internationally, existing studies have largely examined these factors in isolation, leaving limited empirical evidence on how they jointly influence project outcomes within a single integrative framework, particularly in Sri Lanka's Western Province. Addressing this gap, the purpose of this study is to examine the impact of scope creep on the success of construction projects, while evaluating how contractual clarity, stakeholder engagement, and organizational learning are associated with project success.

Using a deductive approach, a quantitative research design was adopted. A structured questionnaire, based on a five-point Likert scale, was distributed among contractors, engineers, architects, project managers and clients. A total of 352 responses were analysed using SPSS software. Reliability testing (Cronbach's $\alpha > 0.7$), correlation, and multiple regression analyses were carried out to test the relationships among the identified variables. The regression model was statistically significant ($p < .001$) and explained 85.6% of the variance in project success (Adjusted $R^2 = .856$). Contractual clarity ($\beta = .226$, $p < .001$), stakeholder engagement ($\beta = .251$, $p < .001$), and organizational learning ($\beta = .633$, $p < .001$) each had a significant positive effect on project success.

Considering the limitations of the study, the researcher suggests conducting longitudinal and qualitative studies in the future to capture behavioural patterns and practical dynamics of scope management across different project settings. By identifying organizational learning as the strongest predictor of project success, followed by stakeholder engagement and contractual clarity, this study contributes an integrative, localized evidence base and actionable recommendations for managers and policymakers in Sri Lanka's construction sector. In doing so, it supports Sustainable Development Goal No. 9 (Industry, Innovation, and Infrastructure) by identifying the specific contractual, relational, and organizational mechanisms through which construction firms in a rapidly urbanizing region can reduce cost overruns and delays and deliver more resilient infrastructure.

Keywords: Scope creep, construction projects, contractual clarity, stakeholder engagement, organizational learning

1 INTRODUCTION

Scope creep has been defined as the uncontrolled expansion of project scope beyond its original boundaries, is recognized as one of the leading causes of project failures in construction [1]. In Sri Lanka, especially in the Western Province where major construction activities are concentrated, projects often suffer from delays, cost overruns, and compromised quality [1]. Studies show that contractual ambiguities, poor stakeholder engagement, and weak organizational learning contribute to the persistence of scope creep [2] [3] [4].This study focuses on examining how scope creep affects project success in Sri Lanka and how contractual clarity, stakeholder involvement, and organizational learning are associated with project success. Thereby contributing to Sustainable Development Goal No. 9: Industry, Innovation, and Infrastructure.

2 RESEARCH GAP

Scope creep has been recognized globally as a leading cause of project failure [5] [6] [3] [4]. However, most existing studies are based on construction projects in developed countries, where organizational systems, resources, and project management practices vary significantly. As a result, there is limited understanding of how scope creep occurs in developing country contexts [7] [8].

In Sri Lanka, a few studies have highlighted common challenges such as unclear contracts and recurring project delays [1]. However, these studies examine the construction sector, without considering the dynamics of individual regions. The Western Province, which consists of majority of the country's large-scale infrastructure and commercial development, faces unique challenges including rapid urbanization, resource constraints, and the involvement of diverse stakeholders. Despite its importance, there is little empirical evidence examining how scope creep impacts project success specifically within this western province.

Furthermore, another gap in literature is the lack of attention to the contractual, behavioural, and organizational dimensions of scope creep. While international research emphasizes the role of stakeholder engagement [3], contractual clarity [5] [6], and organizational learning [4], these factors are often studied individually rather than within a single integrative framework. Although their importance is well acknowledged, [8],indicate that empirical evidence examining how these dimensions collectively influence project success remains scarce in South Asian construction industries.

In the Sri Lankan context, very few studies have explored how these three factors interact with scope creep, and even fewer have narrowed this analysis to the Western Province, where the majority of large-scale construction projects are concentrated. This lack of localized, context-specific research leaves project managers and policymakers without clear guidance on how to minimize the risks of scope creep and strengthen project outcomes.

Therefore, there is a visible empirical gap in understanding how contractual clarity, stakeholder engagement, and organizational learning are associated with project success in the Western Province of Sri Lanka, where scope creep is a known delivery problem. Therefore, this study aims to analyse how scope creep affects construction project success in the western province of Sri Lanka.

Scope creep is not captured here as a standalone variable but is reflected from its effect on project success measured through cost, time, quality, and stakeholder satisfaction to assess the extent to which scope-related changes may have affected project performance [5]. The study adopts an outcome-based perspective in examining scope-related challenges. Rather than relying on a separate measure of the extent of scope changes, attention is given to their potential implications for project performance. Within this framework, contractual clarity, stakeholder engagement, and organizational learning are considered important management practices that can help project teams respond effectively to changes in project requirements. The positive relationships identified between these factors and project success therefore indicate their potential effective management of scope-related changes, even though scope creep was not examined as a separate measurement construct in this study.

Main Research Objective – To examine the role of contractual clarity, stakeholder engagement, and organizational learning as management practices associated with project success in construction projects in Sri Lanka's Western Province.

Main Research Question – How are contractual clarity, stakeholder engagement, and organisational learning associated with project success in construction projects in Sri Lanka's Western Province, where scope creep is a known delivery problem?

3 LITERATURE REVIEW

3.1 *Scope creep in construction projects*

Scope creep is widely recognized as a key contributor to project failure [5]. In the construction industry, it often results in cost overruns, project delays, and disputes between stakeholders [6]. While global studies highlight the importance of managing scope effectively, evidence from developing countries, particularly Sri Lanka, remains scarce [7]. This gap emphasizes the need to examine how scope creep interacts with organizational and managerial factors within the local construction context.

Measuring scope creep directly can be difficult because changes to project requirements may occur gradually and are not always formally recorded [5] [9]. Therefore, scope creep is frequently considered in relation to its consequences for project performance, including cost overruns, delays, and quality problems [8]. Following this approach, this study uses project success as the main outcome and examines whether contractual clarity, stakeholder engagement, and organizational learning are associated with more effective management of scope creep and its potential effects on project outcomes [2] [4].

3.1.1 *Project Success*

Project Success is measured in terms of cost, time, quality, and stakeholder satisfaction [10] argue that success extends beyond meeting schedule and budget, it also includes achieving stakeholder expectations. In Sri Lanka, delays, cost overruns, and quality issues are common often driven by scope creep [1]. Scholars emphasize that factors such as contractual clarity, stakeholder engagement, and organizational learning play a critical role in overcoming these challenges and improving project outcomes [5] [6] [4].

3.1.2 *Contractual Clarity*

Contracts play a central role in defining project scope and setting boundaries for deliverables. According to [5], clear and well-structured contracts reduce the occurrence of disputes and provide a framework for managing unexpected changes. [6] argue that incomplete contracts are a root cause of scope creep, as they allow stakeholders to interpret requirements differently. In Sri Lanka, [1] found that weak contract documentation and unclear terms often lead to misaligned expectations and later scope adjustments.

H1: Contractual clarity has a significant positive effect on project success in construction projects in Sri Lanka's Western Province.

3.1.3 *Stakeholder Engagement*

Active stakeholder involvement is often seen as essential for preventing scope creep. Freeman's Stakeholder Theory [3] emphasizes that early and active participation of stakeholders ensures alignment of expectations and reduces unexpected scope changes. [2] indicated that construction projects supported by robust stakeholder communication experience fewer disputes and schedule delays. Insufficient stakeholder engagement creates misunderstandings that contribute to scope changes. The involvement of clients, contractors, architects, and engineers in Sri Lankan projects makes stakeholder engagement particularly important.

H2: Stakeholder engagement has a significant positive effect on project success in construction projects in Sri Lanka's Western Province.

3.1.4 *Organizational Learning*

Organizational Learning is the capability of a firm to capture, disseminate, and apply knowledge across different projects. [4] highlight that learning organizations are more resilient, as they apply lessons learned to prevent the recurrence of mistakes. [5] emphasizes that lessons-learned processes are essential for reducing risks like scope creep. "In the construction industry, organizations that integrate structured learning practices into their operations are better prepared to control scope effectively. However, in Sri Lanka, research on how organizational learning interacts with scope creep remains limited.

H3: Organizational learning has a significant positive effect on project success in construction projects in Sri Lanka's Western Province.

4 METHODOLOGY

The Triple Constraint Model of Project Management is widely regarded as a foundational theory, emphasizing the interdependence of cost, time, and quality in determining project outcomes [11]. The model was later expanded to include scope emphasizing that uncontrolled scope changes have a direct impact on project success [12]. This perspective aligns closely with the concept of scope creep, where unmanaged changes This directly relates to scope creep, in which uncontrolled scope changes lead to disruptions in cost, schedule, and quality.

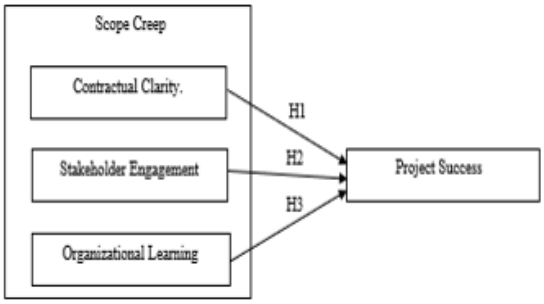


Figure 1. Conceptual framework

Therefore, as explained by the Triple Constraint Model, this study conceptualizes project success as the dependent variable and examines it through three key factors as contractual clarity, stakeholder engagement, and organizational learning, in relation to scope creep. The conceptual framework of the study is presented in Figure 1.

4.1 *Sampling and Procedure*

From the total population of construction stakeholders in Sri Lanka's Western Province, a sample of contractors, engineers, architects, project managers, and clients was considered. A purposive sampling technique was used for this study rather than a probability-based sampling method. This was mainly because there is no complete sampling frame that includes all individuals involved in construction projects across the province. Therefore, methods such as random or stratified sampling were not considered practical. Purposive sampling was appropriate for this study as it allowed the researchers to select respondents who had direct and practical experience in project scope management and project delivery. Since the study focuses on scope creep, obtaining information from individuals who are directly involved in managing project scope was considered more relevant than collecting responses from a general population.

According to the sample-size determination table proposed by [13], the required sample size for the study was 306 respondents. The questionnaire was distributed through direct email outreach to CIDA-registered firms and through professional construction-industry networks, giving contractors, engineers, architects, project managers, and clients equal access to participate Only one response was accepted from each participant since the individual respondent was considered the unit of analysis.

Participation in the study was voluntary. Respondents were not required to provide any personally identifiable information, and anonymity was maintained throughout the data collection process. The questionnaire was used solely for academic research purposes.

A total of 368 responses were received. Following the initial screening of the collected responses, 16 responses were excluded because they contained invalid or inaccurate data. Therefore, 352 valid responses were retained for the final analysis. This represented a usable response rate of 95.7% of the total responses received. The number of valid responses also exceeded the required sample size of 306 respondents and the minimum response rate of 35% suggested by [14].

4.2 *Instrument Development*

By considering similar previous studies, the questionnaire was designed in 3 main sections to rate the scale from 1 – Strongly Disagree to 5 – Strongly Agree. Section A described the demographic information of the target group. Section B measured the Project Success (Dependent Variable), and section C included the questions to study the independent variables (Contractual Clarity, Stakeholder Engagement, Organizational Learning). A filtering question was designed to ensure that only respondents directly in-

volved in construction projects within the Western Province of Sri Lanka were included in the survey.

The Triple Constraint Model highlights the relationship between project scope and key performance dimensions such as cost, time, and quality. Therefore, project success in this study is considered an outcome through which the potential effects of scope creep and other scope-related changes can be examined. Stronger project success indicates more favorable performance across the assessed dimensions, while weaker outcomes may reflect difficulties arising from uncontrolled scope changes during project execution.

4.3 *Instrument Validity and Data Collection Procedure*

The questionnaire items were not developed from scratch but adapted from previously validated scales established in prior project management and construction research, namely contractual clarity from [6] stakeholder engagement from [3], organizational learning from [5], and project success from [9], providing a degree of established content validity prior to distribution. A separate pilot test was not conducted on this sample; this is acknowledged as a limitation, and future replications of this instrument would benefit from a small-scale pretest to confirm item clarity within the Sri Lankan construction context specifically. The questionnaire was distributed electronically via Google Forms to stakeholders linked to organizations registered under the Construction Industry Development Authority (CIDA), reaching contractors, engineers, architects, project managers, and clients through email and professional networks over the data collection period. Only one response was accepted per participant to prevent duplication, and a filtering question at the start of the survey excluded respondents not directly involved in construction projects within the Western Province, ensuring the sample matched the target population.

Table 1. Operationalization table

Variable	Items	References	Measure	Cronbach's Alpha
Contractual clarity	10	[6]	To what extent were the initial objectives and scope of this project clearly defined and communicated to all the stakeholders?	0.702
Stakeholder Engagement	4	[3]	To what extent were the key stakeholders involved in discussions related to project scope ?	0.701
Organizational Learning	12	[5]	To what extent were the lessons learned from past projects can be captured, and applied to manage scope effectively in the project?	0.833
Project Success	16	[9]	To what extent did construction projects achieve its overall success, considering its performance against allocated budget, scheduled timeframe, required quality standards, stakeholder satisfaction, and original objectives and deliverables?	0.826

5 RESULTS AND DISCUSSIONS

According to the demographic profile of the respondents who took part in this study, the majority were contractors and project managers (n=23), followed by engineers (n=24), architects (n=23), and clients (n=47). Most respondents had 6-10 years of industry experience (n=142), ensuring the responses represented perspectives of professionals with significant involvement in construction projects in the Western Province. The participants represented a variety of project verticals, including residential, commercial, in-

frastructure, and hospitality developments, reflecting the different categories of construction projects in the Western province.

Results of the Reliability Analysis indicated strong internal consistency among all variables, with Cronbach's Alpha values above 0.7 for the independent variables (Contractual Clarity, Stakeholder Engagement, and Organizational Learning) and the dependent variable (Project Success). This suggests that the measurement scales used in the study were reliable. This is shown in table 1.

Through the Correlation Analysis (Table 2), the results indicated a significant ($p < 0.05$) positive relationship between the independent variables (Contractual Clarity, Stakeholder Engagement, and Organizational Learning) and Project Success in construction projects in Sri Lanka's Western Province.

To reduce common-method bias, predictor and criterion items were placed in separate sections of the same questionnaire (Section B for project success; Section C for the independent variables). Anonymity was maintained, and multi-item scales were used. A statistical test for common-method variance was not run.

Results of the Multiple Linear Regression analysis highlighted that the overall model is statistically significant at $p < 0.001$, which is below 0.05. The model explained 85.6% of the variance in the dependent variable, Project Success (Adjusted $R^2 = 0.856$), while the remaining 14.4% can be attributed to other external factors not included in the study. Therefore, it can be concluded that the developed model provides a strong fit, as the Adjusted R^2 exceeds the 70% benchmark recommended by [14].

Table 2. Correlation analysis

Variable	Pearson correlation	Significance
Stakeholder engagement	0.606	<0.001
Organizational learning	0.882	<0.001
Contractual clarity	0.647	<0.001

Table 3. Coefficient table

Variable	Unstandardized B	Beta Value	Significance	Rank	Accepted/Rejected
Constant	-1.155		<0.001		
Contractual Clarity	0.452	0.226	<0.001	3	H1- Accepted
Stakeholder Engagement	0. 177	0.251	<0.001	2	H2- Accepted
Organizatio Learning	0. 630	0.633	<0.001	1	H3- Accepted

The coefficients show that contractual clarity ($B = 0.452$, $\beta = 0.226$, $p < 0.001$), stakeholder engagement ($B = 0.177$, $\beta = 0.251$, $p < 0.001$) and organizational learning ($B = 0.630$, $\beta = 0.633$, $p < 0.001$) each have a significant positive effect on project success. H1, H2 and H3 are therefore accepted. The regression equation is:

$$PS = -1.155 + 0.452(CC) + 0.177(SE) + 0.630(OL) \quad (1)$$

where PS = Project Success; CC = Contractual Clarity; SE = Stakeholder Engagement and OL = Organization Learning.

Hence, at a 95% confidence level, all the three hypotheses were accepted: contractual clarity (H1, $\beta = 0.226$, $p < 0.001$), stakeholder engagement (H2, $\beta = 0.251$, $p < 0.001$) and organizational learning (H3, $\beta = 0.633$, $p < 0.001$). Standardized betas are used to rank the variables: organizational learning is strongest, then stakeholder engagement, then contractual clarity. The model accounts for 85.6% of the variance in project success (Adj. $R^2 = 0.856$).

Collinearity statistics for Model 1 showed no concern (organisational learning: tolerance = 0.551, VIF = 1.813; contractual clarity: tolerance = 0.673, VIF = 1.486; stakeholder engagement: tolerance = 0.772, VIF = 1.295).

Table 4. Multicollinearity diagnostic table

Variable	Tolerance	VIF
Stakeholder engagement (SE)	0.772	1.295
Organizational Learning (OL)	0.551	1.813
Contractual Clarity (CC)	0.673	1.486

5.1 *Contractual Clarity vs Project Success*

Previous studies highlight that clear and comprehensive contract helps to reduce disputes, ambiguities, and uncontrolled scope changes [5] [6]. In construction projects, contractual clarity provides a framework that governs expectations, responsibilities, and deliverables, ensuring that all parties are aligned from the initiation. According to [11], well-defined objectives and agreements contribute to smoother execution and reduce late adjustments. In the Sri Lankan context, respondents indicated that unclearly defined contracts frequently lead to disagreements and change orders, resulting in cost overruns and delays. This study's results confirm a strong positive relationship ($B = 0.452$, $\beta = 0.226$, $p < 0.001$) between contractual clarity and project success, emphasizing its role in minimizing scope creep and improving project outcomes.

5.2 *Stakeholder Engagement vs Project Success*

Stakeholder involvement has been identified as a measure against scope creep [3]. Strong communication, active participation, and continuous feedback help to reduce misunderstandings and unexpected changes, which can escalate costs and delay schedules. Empirical research has shown that projects with well-established stakeholder communication experience fewer issues and delays [2]. For construction projects in the Western Province, where multiple stakeholders, clients, contractors, engineers, and architects interact, this study found that stakeholder engagement was positively ($B = 0.177$, $\beta = 0.251$, $p < 0.001$) associated with project success. Effective collaboration and alignment of expectations were shown to reduce the risk of unexpected changes, ultimately strengthening the performance.

5.3 *Organizational Learning vs Project Success*

Organizational learning involves capturing, sharing, and applying lessons from past projects, which enhances success in changing project environments [4]. Previous studies emphasize that organizations which actively establish knowledge, through lessons learned reviews, training, and knowledge-sharing platforms, are capable of managing complexity and reducing repeated mistakes [5].

The results of this study also support this by demonstrating that organizational learning positively impacts ($B = 0.630$, $\beta = 0.633$, $p < 0.001$) project success. Respondents from firms that emphasized training and project reviews indicated fewer recurring errors, better risk anticipation, and improved adaptability when facing scope changes. This strengthens the argument that organizational learning is essential in mitigating scope creep in Sri Lankan construction projects.

6 CONCLUSION

This study set out to examine the impact of scope creep on construction project success in Sri Lanka's Western Province and how contractual clarity, stakeholder engagement and organisational learning are associated with that outcome. The regression results directly answer this research question: all three factors were significant positive predictors of project success (organizational learning, $\beta = .633$; stakeholder engagement, $\beta = .251$; contractual clarity, $\beta = .226$; all $p < .001$), jointly explaining 85.6% of the variance in project success (Adjusted $R^2 = .856$). H1, H2, and H3 were therefore all supported, confirming that contractual, relational, and organizational management practices are central to controlling the effects of scope creep in this context and fulfilling the study's main objective.

For project managers and contractors, organizational learning emerged as the strongest predictor of project success ($\beta = .633$). Since this construct reflects the extent to which lessons from previous projects are captured and applied, construction firms could strengthen this practice through structured post-project reviews and shared knowledge repositories for recording and addressing scope-related issues. Regarding stakeholder engagement ($\beta = .251$), the findings highlight the importance of involving key stakeholders, including clients, consultants, and contractors, in scope-related discussions during the design and pre-construction stages. This may help establish clearer expectations before project execution and reduce the potential for unmanaged changes. Contractual clarity ($\beta = .226$) also

showed a significant positive association with project success. Given its focus on clearly defining and communicating project objectives and scope, organizations could introduce standardized scope-definition checklists and formal sign-off procedures at contract initiation to minimize ambiguity that may contribute to scope creep.

For policymakers and industry bodies such as the Construction Industry Development Authority (CIDA), the findings highlight the potential value of encouraging structured knowledge-management and stakeholder-engagement practices alongside existing technical and financial requirements. Such practices could strengthen contractors' capacity to manage scope-related challenges and support improved project outcomes. In relation to Sustainable Development Goal 9 (Industry, Innovation and Infrastructure), the study contributes by identifying contractual, relational, and organizational practices that are significantly associated with construction project success. These findings provide a practical basis for promoting more effective project management and supporting reliable and resilient construction outcomes in Sri Lanka.

However, the study is limited to construction projects within the Western Province of Sri Lanka, which limits the extent to which the findings can be applied to other regions. Furthermore, the analysis was based only on three organizational factors, indicating that other external factors may also influence project success. This study examines scope creep through its potential implications for project success rather than measuring the magnitude of scope changes using a separate scale. Additionally, the cross-sectional design of this study captures relationships at a single point in time, limiting the ability to draw causal conclusions or observe how these relationships evolve throughout a project's lifecycle. The reliance on self-reported questionnaire data also introduces the possibility of social desirability or perception bias, as respondents' ratings of contractual clarity, stakeholder engagement, and organizational learning reflect individual perspectives rather than independently verified project records. Future studies could strengthen the analysis by incorporating a dedicated scope creep measurement instrument alongside project success measures, allowing the relationship between scope creep and project performance to be examined more directly.

Therefore, future researchers are encouraged to explore additional factors such as leadership style, organizational culture, and project governance mechanisms, while also testing mediating and moderating effects that may explain the relationship between scope creep and project success. Given the cross-sectional design of this study, longitudinal research is particularly recommended to examine how contractual clarity, stakeholder engagement, and organizational learning evolve and influence project success across a project's full lifecycle, rather than at a single point in time. Qualitative studies would further enhance the understanding of how scope creep occurs throughout the project lifecycle and provide deeper insights into practical strategies for managing it in different project environments.

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The Impact of Work-Life Balance on Job Satisfaction Among Entry-Level Women Employees in Five-Star Hotels in Sri Lanka

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ABSTRACT: Entry-level women in Sri Lanka's five-star hotel sector face persistent tension between demanding shift-based work and unequal domestic responsibilities. This study examines the effect of work-life balance on job satisfaction among 102 entry-level female employees in Colombo's five-star hotels, framed by Conservation of Resources theory. A quantitative cross-sectional design was employed. Data were collected via a validated 27-item questionnaire using convenience sampling and analyzed using SPSS through Pearson correlation and simple linear regression. Results confirm a strong positive relationship between work-life balance and job satisfaction. The findings indicate that organizational support for resource conservation is essential for retaining female talent. Practical implications include flexible rostering and family-supportive supervision, contributing to Sustainable Development Goals 5 and 8.

Keywords: work-life balance, job satisfaction, Conservation of Resources theory, five-star hotels, Sri Lanka, entry-level women employees

1 INTRODUCTION

1.1 *Research background*

The overlap of economic trends and changing social roles has placed work-life balance (WLB) firmly on the agenda of organizational management, particularly in high-intensity industries such as hospitality [1]. The issue is strongly gendered: women frequently carry disproportionate caring and household responsibilities alongside professional duties [2]. In five-star hotels, the absence of adequate WLB support can generate acute work-family conflict that undermines psychological health and career progression of female employees [3]. This conflict is especially consequential for job satisfaction (JS), defined as an employee's emotional response to various facets of the job [4]. Although Sri Lankan society is progressive in some respects, traditional expectations regarding women's domestic roles persist and intensify WLB pressures [3]. Understanding how WLB influences the job satisfaction of entry-level women employees is therefore essential for designing sustainable human-resource strategies that support industry stability and growth.

1.2 *Research problem*

While the international literature establishes a clear positive association between WLB and JS in the hotel sector [1], [5], the nature of this relationship among entry-level women employees in Sri Lankan five-star hotels remains under-examined. Although the general importance of the WLB–JS link in service industries is well recognised [1], the relationship is gendered [2] and shaped by local cultural and institutional contexts. A notable geographical and contextual gap therefore exists in the academic literature concerning South Asian luxury hospitality.

1.3 *Research objective*

The objective of this study is to determine whether work-life balance exerts a statistically significant impact on job satisfaction among entry-level women employees in five-star hotels in Sri Lanka.

1.4 *Research significance*

The sustainability and competitiveness of Sri Lanka's five-star hotel sector depend substantially on its ability to retain skilled female labor. This study provides the first empirical evidence on the WLB–JS relationship among entry-level women in Colombo's five-star hotels. It offers practical guidance for hotel human-resource managers seeking to design targeted WLB interventions and contributes to broader societal efforts to empower working women by clarifying the organizational conditions that support their professional success.

2 LITERATURE REVIEW

2.1 *Work-life balance*

Work-life balance is often defined as the feeling of "balance" and "satisfaction" between work and life [6]. Modern conceptualizations have moved beyond the view of work-family conflict as a problem and started to acknowledge the enrichment of work-life [6]. The hotel sector is very challenging to reach WLB as it is open 24 hours a day, has non-standard and long working hours and high emotional labor. These attributes of a job result in ongoing resource depletion. For women the challenge is exacerbated by the fact that there is still a social divide that places women as the primary caregiver for the household and children [2], [3]. As a result, when there is no organizational WLB support, stress levels are higher and work-family conflict is also more prevalent [3]. Sri Lankan hotels, therefore, must have the flexibility to implement work arrangements that will have a positive impact on the general WLB and alleviate the strain between the female staff members [3], [7].

2.2 *Job satisfaction*

Job satisfaction is a multidimensional concept that comes from a positive affective response to the assessment of the work experiences and working conditions [4], [8]. JS is one of the factors affecting HRM in the hospitality sector and it is a key performance indicator of employee engagement, service quality and employee retention [9]. Work relationships and intrinsic rewards are known from numerous studies as the most powerful determinants of JS in hotel environments [10] and as mentioned, other factors can explain JS [11]. Low JS is correlated with higher turnover intentions for women and exerts continual pressure on hotel workforces [9]. As in many competitive urban labor markets like Colombo, it is extremely important to pay attention to relational and intrinsic factors including the factors pertaining to WLB to ensure satisfaction, commitment and productivity of the female workforce [8], [9].

2.3 *Theoretical framework*

The current study is based on Conservation of Resources (COR) theory [12]. According to the COR theory, people seek to gain, keep, defend and improve the resources they desire. Resources are typically classified as objects, personal qualities, conditions and energies [13]. The theory provides a logical explanation about cumulative stress and the relationships between work and home domains in terms of resource exchange [14]. Organizational support is an external factor that can break the vicious circle of loss and stop burnout. However, women working as emotional labour in high pressure hotel settings are especially vulnerable to resource depletion. In accordance with COR theory, the provision of resources by the hotels that support WLB (e.g. flexible schedules and supportive leaders) helps entry-level female employees save personal energy and achieve greater job satisfaction [13].

2.4 *Hypothesis development*

In the context of COR, a work-life balance is considered as a critical condition resource for psychological well-being [13]. A healthy WLB in an entry-level woman at the hotel industry allows her to save her psychological and physical energies and prevents a downward spiral where work requirements intrude into her personal life and reduce her emotional resources for work enjoyment [14]. Flexible schedules or accommodating leadership provide protection against role

conflict stresses of the employee [13]. If a WLB policy allows a woman to preserve her family harmony (which is often a core part of her values), she feels a sense of person–organization fit and gains psychological resources and feels more satisfied with JS [15]. There is some empirical evidence that back up the positive WLB–JS relationship within hospitality and service settings. Job satisfaction is low if WLB is lost, even in high performance working systems [13]. Higher JS is associated with more positive experiences in the work environment, and lower turnover intentions when work is resource-enriching [15]. A major aspect of dissatisfaction for women is stress crossover from work to home [14]. Thus, dual career success is well predicted by having the ability to balance the roles with support from the organization [13]. Based on the above theory and empirical evidence, the following hypothesis is proposed:

H1: Job satisfaction of entry level female employees of five star hotels in Sri Lanka is a positive function of work-life balance.

2.5 *Conceptual framework*

The conceptual model establishes a direct positive relationship between the independent variable (work-life balance) and the dependent variable (job satisfaction), as illustrated in Figure 1.

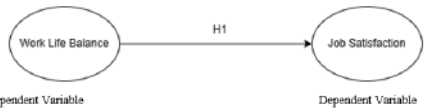


Figure 1. Conceptual framework

The model posits that higher levels of work-life balance lead to higher levels of job satisfaction among entry-level women employees in five-star hotels in Sri Lanka.

3 RESEARCH METHODOLOGY

The study was deductive in nature with a quantitative approach to explore the relationship between work-life balance and job satisfaction among entry level female employees in the 5 star hotels in Colombo [16], [17]. A cross-sectional survey design was used, which took a snapshot of the constructs and allowed for efficient correlational analyses to be performed [13], [14], [18].

3.1 *Population and sampling*

The target population were entry-level women employees (front-office, food-and-beverage service, housekeeping and other operational related) in five-star hotels in Colombo, Sri Lanka. The choice of Colombo was made because it is a city that houses the bulk of the nation's brands and five-star establishments and hence provides the highest and most easily accessible density of the target population. The sampling frame was comprised of female-staff lists provided by the human-resource departments of hotels that allowed access for this research. A non-probability sampling technique, convenience sampling was used because of difficulties in obtaining the full staff lists from all properties, and also due to operational constraints that restricted random sampling. One hundred and twenty questionnaires were sent and 102 were returned (85 percent response rate). The number of final samples of 102 is more than the minimum recommended for simple linear regression and bivariate correlation analyses [17], [18]. While caution must be taken in making any statistical generalization to the national five-star sector, the sample offers a strong suggestion of relationships in the context of the Colombo luxury hotels).

3.2 *Data collection and instrument*

The primary data were collected by using a structured self-administered questionnaire from January to March 2025. There were 10 items measuring work-life balance, 10 items measuring job satisfaction and 7 items of demographic information that were included in the instrument. The multi-item scales were adapted from previous research in the hospitality field. The five-point Likert scale was used for all attitudinal items (from 1: strongly disagree to 5: strongly agree). The questionnaires were provided in sealed envelopes through the human-resources coordinators of the hotels, and collected in sealed collection boxes to keep survey responses anonymous. All participation was voluntary and informed consent was obtained.

3.3 *Data analysis*

IBM SPSS Statistics (Version 28) was used to analyze the data. Data analysis was car-

ried out in the following order: (1) descriptive statistics and demographic profiling; (2) Kaiser–Meyer–Olkin (KMO) test and Bartlett's test of sphericity to measure the sampling adequacy and construct validity; (3) reliability analysis using Cronbach's alpha; (4) Pearson product-moment correlation; and (5) simple linear regression to test the predictive effect of WLB on JS. The statistical significance was calculated at 0.05 level.

4 FINDINGS AND DISCUSSION

4.1 *Demographic profile*

The demographic details of the 102 respondents are summarized below. The sample is largely comprised of early career (57.8 percent with 1–3 years of experience) and well-educated (55.9 percent with bachelor's degree) young people (72.5 percent aged 18–29). This profile of the study reflects its entry-level focus and is a cohort who are most at risk of experiencing work–life collisions due to dual career goals and new personal responsibilities.

Table 1. Age distribution of respondents

Age	Frequency	Percent	Valid %	Cumul. %
18 – 29 years	74	72.5	72.5	72.5
30 – 39 years	27	26.5	26.5	99.0
40 – 49 years	1	1.0	1.0	100.0
Total	102	100.0	100.0	100.0

Table 2. Educational level of respondents

Educational Level	Frequency	Percent	Valid %	Cumul. %
O/L	8	7.8	7.8	7.8
A/L	16	15.7	15.7	23.5
Diploma	21	20.6	20.6	44.1
Bachelor's Degree	57	55.9	55.9	100.0
Total	102	100.0	100.0	100.0

Table 3. Years of experience of respondents

Years of experience	Frequency	Percent	Valid %	Cumul. %
6 Months	31	30.4	30.4	30.4
1–3 Years	59	57.8	57.8	88.2
4–6 Years	12	11.8	11.8	100.0
Total	102	100.0	100.0	100.0

4.2 *Descriptive statistics*

Table 4. Descriptive statistics

	N	Minimum	Maximum	Mean	Std. Dev.
WLB	102	1.50	4.90	3.3490	.50005
JS	102	1.80	5.00	3.4853	.44308

The table presents descriptive statistics for the two main constructs. The mean score for both WLB (M = 3.35, SD = 0.50) and JS (M = 3.49, SD = 0.44) are in the middle range on the 5-point scale, meaning that neither a high degree of balance nor a high degree of satisfaction is reported, but neither are severe deficiencies reported.

4.3 *Validity and reliability*

The KMO value was 0.788 (which is above the conventional 0.60 value) and the Bartlett's test of sphericity was statistically significant ($\chi^2 = 700.76$, df = 190, $p < .001$), thus confirming the sampling was adequate for analysis. The WLB scale (10 items) and JS scale (10 items) had Cronbach's alpha of 0.793 and 0.755 respectively, which is higher than the recommended level of 0.70 [16]. The internal consistency of the combined 20 items was high with an alpha of 0.876.

Table 5. KMO and Bartlett's test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy	.788
Bartlett's Test of Sphericity – Approx. Chi-Square	700.760
df	190
Sig.	<.001

Table 6. Reliability analysis

Scale	Cronbach's Alpha	N of Items
WLB	.793	10
JS	.755	10
Combined (20 items)	.876	20

4.4 *Correlation analysis*

The results indicated a strong, positive and statistically significant correlation between WLB and JS ($r = .798$, $p < .001$) showing a high relationship between the variables. That is why one can say that there is a relationship between the WLB of the respondents and their job satisfaction.

Table 7. Correlation analysis

	WLB	JS
WLB – Pearson Correlation	1	.798**
Sig. (2-tailed)		<.001
JS – Pearson Correlation	.798**	1
Sig. (2-tailed)	<.001	

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

4.5 *Regression analysis*

Table 8. Model summary

Model	R	R Square	Adjusted R^2	Std. Error
1	.798a	.637	.634	.26819

a. Predictors: (Constant), WLB

Table 9. ANOVA analysis

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	12.635	1	12.635	175.673	<.001b
Residual	7.193	100	.072		
Total	19.828	101			

a. Dependent Variable: JS; b. Predictors: (Constant), WLB

Table 10. Regression coefficients

Model	B	Std. Error	Beta	t	Sig.
(Constant)	1.116	.181		6.179	<.001
WLB	.707	.053	.798	13.254	<.001

a. Dependent Variable: JS

Simple linear regression was used to evaluate the predictive power of WLB for JS. The model was significant ($F = 175.67$, $p < .001$), and accounted for 63.7 percent of the variance in job satisfaction ($R^2 = 0.637$, adjusted $R^2 = 0.634$). The unstandardized coefficient for WLB was $B = 0.707$ ($\beta = 0.798$, $t = 13.25$, $p < .001$), meaning that a unit increase in WLB is related to a unit increase in JS of 0.707. The results support Hypothesis H1 very well.

4.6 *Discussion*

The correlation between WLB and JS is positive and significant ($r = .798$; $R^2 = 0.637$) which indicates that the variance in the WLB and JS for the entry-level female staff members in the five-star hotels in Colombo can be explained by more than 60 percent of the variance in the ability to balance work and personal life. This is in keeping with international hospitality studies that show that employee well-being-focused systems are a key determinant of satisfaction [1], [13] and that balance-supportive structures increase job satisfaction [10]. The results make sense within COR theory: those women who feel their work-life balance is satisfactory have more emotional resources to safeguard to deliver quality service [14]. Within Sri Lankan culture, there is a greater value on flexibility in family time and organizational sensitivity to family responsibilities that extends beyond that of financial incentives [3]. Additionally, there was no statistically significant difference among the various age, education and tenure groups in the sample in the relationship between WLB and JS (one-way ANOVA: $F = 1.065$, $p = .349$), indicating that the relationship between WLB and JS is quite general within the age, education and tenure groups in the sample. The results suggest that from a managerial perspective, scheduling practices that are rigid and pressurized should be replaced by practices that promote the enrichment of resources through the use of human resources. Concrete levers for enhancing satisfaction and retention are flexible rostering, compressed work weeks and family supportive supervisor behaviours [2], [13]. Such practices also contribute to the United Nations Sustainable Development Goal 5 (Gender Equality) by tackling structural barriers that impact women's career continuity and Goal 8 (Decent Work and Economic Growth) by creating safer, more equitable and productive workplaces. The present study has several limitations and future research is needed. There are a number of caveats to note. Strong causal inference is not possible in the cross sectional design as it would be possible in a longitudinal design, where one can examine the trajectories of resource depletion and recovery predicted by COR theory [14]. The methodological limitations of convenience sampling and the fact that the sample was restricted to Colombo five-star hotels reduce the ability to make generalizations; future research should employ stratified or random sampling of hotels and include properties outside the capital. Only self-report measures were used, which may introduce common method bias – future studies will benefit from multiple sources of data and

from objective indicators. Lastly, the possible role of mediators (such as perceived organizational support) and moderators (such as family supportive supervisor behaviour) would enhance knowledge on the mechanisms between WLB and JS [1].

5 CONCLUSION

The results of this study show work-life balance is significant in predicting job satisfaction among entry level female employees in the five star hotels in Colombo. The results are in line with Conservation of Resources theory, indicating that supportive organizational practices that enhance the availability of resources can break cycles of resource depletion and promote the psychological resources needed for effective service work. Hotel managers are thus recommended to have flexible employee rostering, supervisor training to support family, and specific employee assistance programs (such as childcare support, emergency family leave, etc.). These interventions have the potential to enhance the wellbeing of the individual and their retention, as well as concrete contributions to national and global agendas for gender equality and decent jobs.

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Smart Port Adoption and Trade Competitiveness: A Sri Lankan Pilot and DiD Protocol

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ABSTRACT: This paper develops a reproducible difference-in-differences (DiD) protocol for evaluating discrete smart-port adoption in emerging economies. It defines the treatment registry, port-by-month panel, outcomes, comparator eligibility, staggered-adoption estimators, and diagnostic gates needed for causal interpretation. A descriptive pilot applies the measurement framework to official 2024 and 2025 records for Colombo and Hambantota. The pilot documents observed operating changes, but it does not estimate a DiD effect, test parallel trends, or attribute changes to digitalisation. The contribution is a transparent causal-inference protocol grounded in official pilot data rather than illustrative results.

Keywords: smart port, port digitalisation, difference-in-differences, port performance, trade competitiveness, emerging economies

1 INTRODUCTION

Ports are central nodes in maritime logistics and regional trade, yet the effect of digital investments on their performance is often inferred from case narratives rather than a defensible counterfactual. Automation, sensors, port community systems, digital twins, and data-driven scheduling may reduce delay and improve information flows, but observed throughput can also change because of demand, route reconfiguration, capacity additions, or wider supply-chain shocks [1].

This distinction matters particularly for emerging-economy ports. Digital projects are frequently bundled with physical expansion, electrification, and commercial repositioning. A before-and-after comparison can therefore describe a change, but cannot isolate the technology component. A credible evaluation requires outcomes for treated ports and suitably comparable ports before and after a documented operational go-live, together with explicit tests of whether their pre-adoption trajectories support the comparison.

Sri Lanka provides a useful pilot setting because official port reports document recent operating changes. Colombo handled 7,792,069 TEU in 2024 and 8,291,178 TEU in 2025 [2]. Hambantota reported 53,170 and 428,036 TEU, respectively, and 579,362 and 726,153 roll-on/roll-off units [3]. These records motivate an evaluation, but neither series alone identifies the effect of smart-port adoption. They are treated here as descriptive pilot data, not as causal evidence.

The paper makes three contributions. First, it defines a measurable smart-port treatment and a port-by-month DiD design. Second, it specifies outcome scales, comparator eligibility, estimation, and robustness checks so that the design can be reproduced and audited. Third, it demonstrates the measurement layer with the two Sri Lankan official-data series while making the pilot's inferential boundary explicit. Section 2 positions the work in the relevant literature; Sections 3 and 4 state the research questions and protocol; Sections 5 and 6 report the descriptive pilot and the planned

causal analysis; Sections 7 and 8 give limitations and conclusions.

2 RELATED WORK AND RESEARCH GAP

The review links smart-port technologies to port performance and trade systems, then identifies the causal-inference requirements that the sector-specific literature rarely satisfies.

2.1 *Smart ports, logistics and performance*

Smart-port scholarship describes a broad portfolio of technologies and operating capabilities. Heilig, Lalla-Ruiz, and Voss [4] frame the digital transformation of maritime ports, while Molavi, Lim, and Race [5] decompose smart-port capability into operational, environmental, energy, and safety dimensions. Port performance is nevertheless multi-dimensional: vessel time in port, terminal throughput, service reliability, and connectivity capture different mechanisms and should not be collapsed into an unexamined index. The Container Port Performance Index therefore Centre's its comparison on vessel time in port [6]. The port-productivity literature links governance, technology, and management to measurable efficiency and competitiveness [7], while port economics connects terminal operations with hinterlands, shipping networks, and trade systems [8]. Research on maritime digitalization also documents adoption incentives and information-infrastructure constraints [9]. Together, these strands establish plausible mechanisms, but they do not generally provide causal estimates for discrete smart-port adoption in emerging-economy ports.

2.2 *Causal inference for port investment*

DiD is suitable when an intervention has a date, untreated comparison units, and outcomes observed before and after treatment. Its standard formulation compares changes in treated and control units under a parallel-trends assumption [10], with fixed-effects implementations discussed by Angrist and Pischke [11]. However, a conventional two-way fixed-effects coefficient can be misleading when adoption is staggered and effects differ across cohorts. Goodman-Bacon [12] identifies the problematic comparison weights, and Callaway and Sant'Anna [13], de Chaisemartin and D'Haultfoeuille [14], and Sun and Abraham [15] provide estimators that retain interpretable cohort and event-time effects. These developments are essential rather than optional for a multi-port digitalization study.

2.3 *Research gap*

The gap is therefore not simply a lack of smart-port cases. It is a lack of evaluations that define the intervention, outcome scale, control pool, and identifying assumptions tightly enough to distinguish adoption from coincident operational or trade changes. This paper addresses that gap with a protocol that separates descriptive pilot evidence from the future causal analysis and makes failure of an assumption an informative result rather than a reason to retain an unsupported claim.

3 RESEARCH SCOPE AND QUESTIONS

The study asks whether a discrete, operationally verified smart-port adoption changes port performance and downstream trade competitiveness relative to comparable ports. O1 is to construct a reproducible treatment registry and port-by-month panel. O2 is to measure vessel turnaround time, throughput, and port-routed trade value on declared scales. O3 is to estimate and stress-test treatment effects only when the comparator and pre-trend requirements are met. The two-port pilot serves O1 and O2; it does not by itself satisfy O3.

RQ1: After a qualifying adoption event, do treated ports experience a different change in operational outcomes than eligible comparison ports? RQ2: Is any estimated operational effect accompanied by a change in port-routed trade value? RQ3: Do the conclusions survive tests of pre-trends, staggered adoption, comparator support, spillovers, simultaneous capacity changes, and alternative treatment intensities?

The protocol distinguishes the hypothesized pathway from smart-port adoption to operational performance and trade competitiveness from the empirical comparison

needed to test it. The mechanism is not treated as evidence that a downstream effect has already occurred.

4 EMPIRICAL DESIGN AND MEASUREMENT

The unit of analysis is port p in calendar month t. The primary dataset is an unbalanced port-by-month panel containing at least 24 pre-adoption months for each treated cohort, the documented adoption date, and a post-adoption follow-up period sufficient to observe implementation dynamics. Annual totals are retained for the descriptive pilot only; they are not adequate for an event study or a credible parallel-trends test.

4.1 *Treatment definition and analysis population*

A qualifying adoption is a discrete operational go-live of a defined smart-port component, such as automated equipment control, a port community system, a terminal digital twin, or an integrated IoT operating platform. The treatment registry records component, terminal or port coverage, go-live month, documentary source, and concurrent capacity project. The port-level treatment indicator is binary, time-invariant, and nominal. The post-adoption indicator is binary, time-varying, and equal to one from a port's verified go-live month onward. A port with an undated, purely planned, or bundled intervention that cannot be separated from major capacity expansion is not assigned to the binary-treatment analysis. Eligible controls are ports in the same regional market that have no qualifying adoption in the estimation window or are not yet treated at month t.

$$Y_{pt} = \alpha + \delta\,(Treated_p \times Post_t) + \mu_{pt} + \lambda_t + X_{pt}\,\gamma + \varepsilon_{pt} \quad (1)$$

In Equation (1), the dependent variable is each outcome in Table 1, and the interaction coefficient is the treatment effect for a common adoption cohort. Port and calendar-month fixed effects absorb stable port characteristics and common shocks, while pre-specified time-varying controls capture port capacity, service or route composition, national trade activity, and measured shipping-market shocks. Standard errors are clustered by port. Equation (1) is reported only for a single-cohort or otherwise justified design; it is not the primary estimator when adoption is staggered.

$$Y_{pt} = \alpha + \sum_{k \neq -1} \beta_k D^k_{pt} + \mu_p + \lambda_t + X_{pt}\,\gamma + \varepsilon_{pt} \quad (2)$$

For staggered adoption, the primary estimates are cohort-specific average treatment effects using Callaway and Sant'Anna and an event-time specification using Sun and Abraham. Each event-time indicator marks a month relative to a port's verified go-live date, with the month before adoption omitted. Pre-adoption lead coefficients are examined jointly and graphically; non-zero leads, weak overlap, or short pre-periods prevent a causal interpretation. Lags show implementation dynamics only after the diagnostic requirements are met.

4.2 *Outcomes, scales and data structure*

Each outcome is estimated separately. Vessel turnaround is the median elapsed hours from arrival to departure for completed calls in a port-month. Throughput is a count reported separately as TEU and roll-on/roll-off units; these series are not added together. The trade outcome is monthly port-routed export and re-export value in constant United States dollars, included only where customs or port-community-system records can link value to the port. Log transformations are specified for strictly positive skewed measures, with the raw-unit model retained as a robustness check. Missing observations, revisions, and changes in reporting coverage are recorded rather than silently imputed.

Table 1. Outcome definitions and measurement scales for the planned port-by-month panel

Outcome	Operational definition	Scale and analysis form	Hypothesized direction
Vessel turnaround	Median arrival-to-departure hours per port-month	Ratio; log median hours and raw-hours check	Decrease
Throughput	TEU or roll-on/roll-off units per port-month, modelled separately	Count; log(value + 1) and raw-count check	Increase
Trade competitiveness	Port-routed export and re-export value in constant USD per month	Ratio; log value and raw-value check	Increase, if pass-through occurs

Comparator selection is empirical rather than rhetorical. Before estimation, each treated port is matched or reweighted using pre-treatment turnaround, throughput, transshipment share, capacity, and trade exposure; balance diagnostics and the available support determine whether a comparison is retained. The event registry also flags ports sharing a feeder network, shipping service, or simultaneous capacity expansion with a treated port. Such links can create spillovers or confounding shocks. The protocol responds by excluding affected controls, estimating leave-one-port-out models, adding measured concurrent events, and reporting the change in estimates. A secondary treatment-intensity design codes each component on a 0-4 ordinal implementation scale. It is analyzed separately with a stated dose-response specification and is never interpreted as the binary DiD esteemed.

5 DATA AND DESCRIPTIVE PILOT

The pilot sample comprises publicly reported annual 2024 and 2025 operational records for Colombo and Hambantota. It contains two ports, two years, and incomplete indicator coverage; it therefore cannot form a treatment-control panel, estimate an event study, or test parallel trends. Its purpose is narrower: to demonstrate the outcome definitions, source traceability, and reporting format that the full monthly panel will use. Colombo's container series is drawn from the Sri Lanka Ports Authority [2]; Hambantota's container, roll-on/roll-off, and total-cargo series are drawn from the Hambantota International Port Group [3].

Table 2. Descriptive pilot: officially reported operating indicators, 2024–2025 (sources: [2], [3])

Indicator	2024	2025	YoY
Colombo container throughput (TEU)	7,792,069	8,291,178	+6.4 %
Hambantota container throughput (TEU)	53,170	428,036	+705 %
Hambantota roll-on/roll-off (units)	579,362	726,153	+25%
Hambantota total cargo (million tones)	3.00	8.24	+175 %

The pilot shows that Colombo container throughput increased by 499,109 TEU (6.4%) and Hambantota container throughput increased by 374,866 TEU (705%) between the reported years. Hambantota roll-on/roll-off activity rose by 146,791 units (25%), and total cargo increased from 3.00 to 8.24 million tones (175%). These are observed differences, not DiD estimates. They may reflect technology investment, capacity additions, traffic rerouting, commercial strategy, demand, or other events. The revised manuscript does not attribute them to smart-port adoption.

6 ESTIMATION AND ROBUSTNESS PROTOCOL

No illustrative regression coefficient, pre-trend result, or event-study figure is reported. A causal estimate will be produced only after the treatment registry and monthly panel pass the following gates: documented go-live dates; an eligible comparator pool with pre-treatment support; at least 24 pre-adoption months; separate outcome models; and transparent accounting for missingness, capacity expansions, and shared-network exposure. This replaces the previous demonstrative values with a replicable standard for empirical implementation.

The analysis first reports raw port-month trajectories and balance diagnostics. It then estimates cohort-specific effects with Callaway and Sant'Anna, event-time effects with Sun and Abraham, and a conventional two-way fixed-effects model only as a labelled comparison. Robustness checks include joint tests of pre-adoption leads, placebo adoption dates, alternative comparator sets, leave-one-port-out estimates, alternative outcome transforms, and exclusion of ports affected by contemporaneous capacity or route changes. The binary and ordinal-intensity treatments are reported as distinct estimates. Results that fail any identification diagnostic are described as descriptive associations rather than causal effects.

This protocol also improves practical applicability. Comparable ports need not be identical; they need sufficient pre-treatment support on defined outcomes and exposures. Where support is absent, the appropriate result is to narrow the estimand, use a different design, or report that the causal comparison is not feasible. This discipline is especially important where adoption is gradual, bundled, or accompanied by new terminal capacity.

6.1 *Practical implications*

For port authorities, the protocol turns evaluation into an implementation requirement: record an operational go-live date, component coverage, data lineage, and concurrent projects. For development financiers and policymakers, it separates a promising operating trend from evidence of an investment return. The resulting panel can show whether efficiency gains occur, whether they are robust to comparator and timing choices, and whether any benefit passes through to port-routed trade rather than assuming that it does.

7 LIMITATIONS AND FUTURE WORK

The current limitation is empirical scope, not a hidden statistical result. The public pilot does not identify treatment dates, control ports, monthly outcomes, or a trade-value panel. Smart-port adoption may remain endogenous even after fixed effects and pre-trend checks, while component bundles, spillovers, and concurrent capacity investment can complicate the estimand.

8 CONCLUSIONS

Smart-port investment may improve operational performance and trade competitiveness, but those claims require a credible counterfactual. This paper provides the necessary protocol: a verified treatment definition, port-by-month outcomes on declared scales, eligible comparators, staggered-adoption estimators, and explicit diagnostic gates. The Sri Lankan pilot anchors the framework in official operational data and documents real year-to-year changes, while correctly withholding causal attribution. The contribution is a transparent route from an observed port-performance change to a testable causal estimate, rather than an unsupported assertion that the change was caused by digitalization.

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Blockchain Smart Contracts for Multimodal Freight Transparency: A Structured Review and Design Framework

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ABSTRACT: This paper presents a structured literature review of blockchain-enabled smart contracts for multimodal freight transparency and derives a design framework from the evidence. The retained corpus comprises 24 cited sources, including seven focal studies selected for their direct contribution to blockchain, smart-contract, logistics, and multimodal-transport questions. The synthesis is organized as a dependency chain from supply-chain foundations, through contract engineering and IoT evidence, to multimodal interoperability and governance. It finds that verifiable, deterministic obligations can be digitized, but value depends on neutral governance, shared semantics, legally recognized records, and trustworthy data inputs. The paper contributes a framework that translates these findings into four design commitments: cross-leg orchestration, federated governance, semantic and legal interoperability, and corridor-specific institutional fit. The review does not claim a PRISMA-compliant screening flow because an auditable database export and historical screening log were not retained; it instead reports the corpus and analytical rules transparently.

Keywords: blockchain, smart contracts, multimodal freight, supply chain transparency, interoperability

1 INTRODUCTION

International container movements generate documentary exchanges among carriers, terminals, forwarders, banks, customs authorities, and cargo interests. Delayed reconciliation, duplicated documents, and disputes over cargo condition arise in this information layer. Since the distributed-ledger design of Nakamoto [1] and Szabo's account of self-enforcing digital agreements [2], blockchain and smart contracts have been proposed as ways to maintain a shared, tamper-evident record and execute obligations when verifiable conditions are met. Early supply-chain work links the technology to traceability, trust, and operational objectives [3], [4]. However, the closure of the Maersk-IBM Trade Lens platform in 2023 illustrates that technical feasibility alone does not sustain an industry network [7].

This paper asks where the literature establishes a credible role for blockchain and smart contracts in freight logistics, what evidence exists for their engineering and deployment, and what design implications follow for multimodal freight transparency.

Rather than treating the absence of studies in a region as a gap in itself, the paper examines whether findings from published settings can transfer to corridor-specific institutional conditions. The contribution is a structured evidence synthesis and a framework that connects reported findings, their boundaries, and concrete design commitments for a federated freight-documentary network. It does not present an implemented architecture or causal performance results.

2 REVIEW DESIGN AND CORPUS

The original review query combined three concept blocks: (blockchain OR distributed ledger OR smart contract*) AND (logistics OR supply chain OR freight OR maritime OR multimodal OR intermodal) AND (transparency OR traceability OR document* OR bill of lading OR interoperability). The stated sources were Scopus, Web of Science, IEEE Xplore, ScienceDirect, and Google Scholar. The retained files do not contain a database export, de-duplication record, dates of each search, or a historical title-and-abstract screening log. Accordingly, the revised manuscript does not reconstruct or estimate a PRISMA flow, and it is described as a structured literature review rather than a PRISMA-compliant systematic review.

The auditable corpus contains 24 sources cited in this paper. Seven focal studies [5], [6], [9]-[13] were selected because each address at least two of the following: blockchain or smart-contract implementation, logistics or transport, multi-party coordination, and a conceptual, formal, demonstrator, or deployment contribution. Seventeen additional sources [1]-[4], [7], [8], [14]-[24] provide foundations, reviews, regulation, industry context, or regional evidence. Each focal study was coded for unit of analysis, evidence maturity, directness to multimodal freight, contract-engineering content, treatment of governance, and transferability boundary. This coding frame, and not an unverified count of earlier search results, is the reproducible basis for the synthesis and Table 1.

3 THEMATIC FINDINGS

3.1 *Foundations and systematic evidence on blockchain in supply chains*

The four themes form a dependency chain rather than a set of independent topics. The first establishes the conditional value and adoption barriers reported in supply chains. The second asks whether smart contracts can encode and execute obligations. The third tests the reliability and confidentiality of physical-data inputs. The fourth considers whether those contracts, data, and documents can be interpreted and governed across transport modes and organizations. Reading the themes in this order distinguishes technical possibility from a deployable multimodal arrangement. In the foundational stream, Saberi et al. [3] identify inter-organizational, intra-organizational, technical, and external barriers, while Kshetri [4] links blockchain to provenance and trust among parties without a common intermediary. Hackius and Petersen [14] likewise report interest tempered by regulatory uncertainty and reluctance to share data with competitors.

Review studies qualify these early promises. Pounder et al. [5] map technology, trust, trade, and traceability or transparency themes across supply-chain, transport, and logistics research. Bernie's et al. [6] conclude that value is conditional and that concrete implementation evidence remains limited. Casino et al. [15], Queiroz et al. [16], Wang et al. [17], and Treiblmaier [18] similarly identify immature evaluation, adoption constraints, and weak links between technical features and supply-chain outcomes. In maritime and port contexts, Tsiulin et al. [19] find that many initiatives remain at pilot stage. These sources establish a problem setting and boundary conditions; they do not, by themselves, verify a cross-leg freight solution.

3.2 *Engineering demonstration and deployment of smart contracts*

The second theme moves from claimed benefits to contract design and execution. Alqarni et al. [9] survey implementation, deployment, audit, and operational aspects of smart contracts across logistics settings. Dolgui et al. [10] model smart-contract design and execution as a state-controlled, event-driven process in which physical operations are connected to cyber information services. The work provides a formal execution logic, but it is not a multimodal documentary architecture.

Agrawal et al. [11] demonstrate a blockchain-based collaborative framework on Ethereum with network architecture, interaction sequences, and verification logic. Chang et al. [20] examine the redesign of trade and letter-of-credit processes, and Bavassano et al. [21] discuss managerial conditions for blockchain in shipping. Collectively, these studies support the feasibility of digital agreement execution, while also indicating that business-network governance remains a limiting condition.

3.3 *IoT integration on permissioned ledgers*

The third theme concerns the link between physical events and contractual state. Aleksieva et al. [12] combine IoT sensing and smart contracts on Hyperledger Fabric for cross-docking warehouses and transport. Their role-differentiated permissions show that a monitoring-only insurer can observe signed events without receiving write access. The study supports the feasibility of controlled data sharing, but it also identifies an enduring boundary: a ledger preserves the integrity of an input without proving that a sensor reading or other oracle input was truthful. Any automatic freight obligation must therefore specify data provenance, signing, exception handling, and human escalation.

3.4 *Multimodal interoperability, governance and platform failure*

The final theme connects contract logic and trusted inputs to interoperability. Scrocca et al. [13] model business agreements as ontological smart contracts in a multimodal transport setting, demonstrating the value of a machine-readable agreement layer. Although the application concerns passenger mobility, its transferability lies in the semantic principle: parties cannot verify a contractual state across organizational boundaries unless its terms use shared, implementation-independent meanings.

Regulation and governance provide the complementary institutional layer. The European Union's electronic freight transport information framework requires acceptance of regulatory freight information through certified platforms without prescribing a particular ledger [8]. Trade Lens was discontinued in 2023 after industry collaboration and a sustainable business model did not materialize [7]. Together with the review evidence [5], [6], [19], this case cautions against treating a single platform operator as a neutral network coordinator. Governance, data rights, and participant incentives are architectural requirements, not post-deployment details.

4 COMPARATIVE SYNTHESIS AND EVIDENCE ASSESSMENT

Table 1 makes the evidentiary boundary explicit. It assesses evidence maturity and directness to the multimodal freight problem rather than applying a single quality score to conceptually different reviews, models, and demonstrators. None of the focal studies combines cross-leg documentary orchestration, neutral network governance, semantic interoperability, and a corridor-specific institutional design. The framework in Section 5 is a synthesis of these partial contributions, not evidence that a complete architecture has already been deployed.

Table 1. Evidence-maturity and transferability assessment of the seven focal studies

Focal study	Evidence maturity and directness	Finding used in synthesis	Transferability boundary
Pournader et al. [5]	Systematic review; indirect	Maps trust, trade, and traceability themes	No multimodal architecture
Berneis et al. [6]	Systematic review; indirect	Value is conditional; cases remain scarce	No corridor-level validation
Alqarni et al. [9]	Survey; moderate	Covers deployment and audit trade-offs	Mode-agnostic evidence
Dolgui et al. [10]	Formal model; indirect	Supports state-controlled event logic	Intra-firm scheduling focus
Agrawal et al. [11]	Demonstrator; indirect	Shows network and verification artefacts	Procurement, not freight legs
Aleksieva et al. [12]	Demonstrator; indirect	Shows signed IoT and differentiated access	Single-operator scope
Scrocca et al. [13]	Ontology artefact; moderate	Shows machine-readable agreements	Passenger-mobility context

5 FRAMEWORK FOR MULTIMODAL FREIGHT TRANSPARENCY

The paper's contribution is a findings-derived framework that translates partial evidence into design commitments. It begins with the principle that only deterministic, externally verifiable obligations should be automated. A signed gate-in, a confirmed custody handover, or a payment condition can be represented as a contract state; a quality dispute or regulatory discretion remains a human decision supported by recorded evidence. The framework therefore treats a smart contract as one component of a documentary control system, not as a substitute for governance or legal judgement.

Four linked commitments follow. First, cross-leg orchestration links state transitions across road, rail, port, and sea legs without assuming that one operator owns every process. Second, federated governance distributes nodes, write permissions, audit rights, and dispute roles across a consortium rather than a commercial rival. Third, semantic and legal interoperability aligns contract fields, documentary vocabularies, and regulatory acceptance rules before a transaction is automated. Fourth, contextual transferability requires the framework to be adapted to corridor-specific customs procedures, documentary practice, financing arrangements, institutional trust, and data stewardship. The South Asian point is thus an institutional test of transferability, not an unsupported claim that a regional absence alone proves a gap.

6 RESEARCH GAPS AND AGENDA

Three gaps remain after this assessment. G1 is cross-leg orchestration: the focal literature supplies elements for individual processes but not a documented design that coordinates title, milestone, and payment states across multiple freight legs [9]-[12]. G2 is governance-to-architecture translation: the literature identifies governance and standardization barriers but gives limited operational guidance on neutral node distribution, symmetric data rights, and observer roles [5], [6], [19]. G3 is institutional transferability: evidence from published demonstrators cannot be assumed to apply to a Colombo-anchored or other South Asian corridor without examining its legal, customs, financing, and inter-organizational conditions [22]-[24]. Future work should evaluate the framework through a documented corridor pilot, publish the participant and data-governance rules, and report implementation failures as evidence rather than as exceptions to be omitted.

7 CONCLUSIONS

Blockchain-enabled smart contracts may improve freight-document transparency where obligations are deterministic, data inputs are trustworthy, and participants accept shared rules. The evidence reviewed here does not establish a universally deployable solution or an implemented corridor architecture. It does, however, support a disciplined framework that joins event-driven contract logic to federated governance, semantic and legal interoperability, and institutional fit. By reporting the retained corpus, coding rules, evidence boundaries, and framework explicitly, the revised paper makes its contribution and limitations available for scrutiny.

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Time Series Modeling Temporal Patterns in Saltwater Fish Production in Hambantota, Sri Lanka

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ABSTRACT: The saltwater fishing industry plays a major role in the Sri Lankan economy and also in the livelihood of coastal communities. Thus, the future directions of saltwater fish harvest are vital in developing this industry. Therefore, making predictions about the saltwater fish harvest will be important for supporting evidence-based policy decisions and ensuring the long-term sustainability of marine resources. Among other fishing centers in Sri Lanka, Hambantota makes a significant contribution to the country's marine fishing sector. Hence, this study aims to predict saltwater fish harvest in Hambantota. Monthly fish harvest data for the past 8 years from 2016 to 2023, have been utilized for the analysis. In the preliminary analysis, seasonal and trend components in the time series were identified using decomposition techniques. Unit root tests such as the Augmented Dickey-Fuller (ADF) test and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) were used to test stationarity. Holt-Winters models, after applying the transformations, log, Box-Cox, reciprocal transformation, square-root, cube-root, as well as normalization and standardization. Further, the SARIMA model was fitted to the data. Holt-Winters models outperformed the SARIMA model. The Holt-Winters model with the reciprocal transformation was recommended for future forecasting, as it has the lowest MAPE (16.60%). According to the model's prediction, this study suggests that fish harvest in Hambantota will also decrease, and that policies should be made to improve the harvest, unless it becomes a significant problem for the Sri Lankan saltwater fishing industry. Major anomalies, including disruptions caused by the COVID-19 pandemic (2020) and the X-Press Pearl disaster (2022), which were directly linked to the fishing industry in Sri Lanka, were identified through visual inspection and statistical methods, with plans for further anomaly correction.

Keywords: Fish harvest, Hambantota, Holt-Winters models, SARIMA, Time series, Transformations

1 INTRODUCTION

The coastal fisheries are an important sector of the nation's economy, which plays a major role in food security, employment generation, and the livelihoods of the rural communities. Hambantota, in the southern coastline, is of special significance among the key landing points in the fish industry. The Tangalle Fisheries Division in Hambantota District is one of the major marine fisheries regions in Sri Lanka, contributing substantially to the country's marine fishing sector, with a high concentration of fishing villages and active fishers [1]. Hence, the main aim of this study is to identify patterns in Hambantota fish harvest and to fit forecasting models to provide recommendations for the fishing industry. The fish harvest data for Hambantota show significant fluctuations with a general downward trend for the past eight years (2016-2023). The trend may reflect fluctuations in catch rates in the past, possibly due to variations in fish stocks or

fishing pressures, or even to wider environmental and socio-economic factors such as the COVID-19 pandemic (2020) and the X-Press Pearl disaster (2022) that impact fishing efforts.

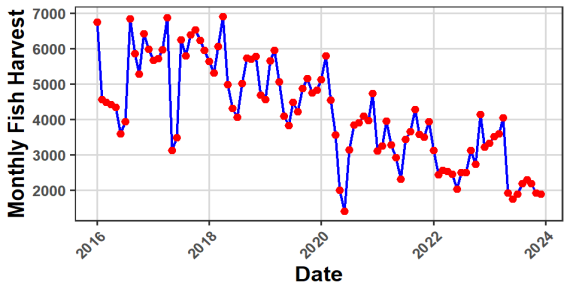


Figure 1. Monthly fish harvest in Hambantota

These dynamics are apparent when displayed as a time series plot of the harvest data, which shows both short-term variability and a long-term decline in harvest during the study period. This highlights the necessity of ongoing monitoring of the fish landing trends in Hambantota to support evidence-based fisheries management, sustainable use of fish resources, and sustainable long-term viability of the coastal fisheries industry.

2 LITERATURE REVIEW

Fish production forecasting study is of critical importance in sustainable fisheries management, particularly in developing countries such as Sri Lanka that have a high dependence on fish to meet food and nutritional demands and for economic gains. Different statistical methods are used for the prediction of future data related to the agricultural and fisheries sector, with Auto Regressive Integrated Moving Average (ARIMA) being one of the most widely used time series models. Box and Jenkins introduced ARIMA models, which are powerful models as they can be applied to non-stationary data through differencing, and they can forecast accurately for a short time. In previous studies, the models ARIMA and similar models have been used with success to predict agricultural production, such as milk and maize production in various regions, proving their robustness to handle data variations. The study contributes to the existing literature by using the ARIMA (1,1,1) model for forecasting trends in fish production in Sri Lanka for the period 1972 to 2016 and by highlighting the suitability of this model for forecasting trends in fisheries, thus aiding in policy-making and management decisions [2].

Fisheries modelling has come a long way from simple models, such as surplus production and age-structured models, which are useful in stable and data-limited fisheries, to more sophisticated ecosystem-based models and machine learning techniques that can better represent multi-species and non-linear interactions in more complex and uncertain systems. Ecosystem models provide broad-scale understanding of food web interactions and long-term ecosystem management but are very data-intensive and resource-intensive, so they can be difficult to scale. Neural networks and random forests are examples of machine learning methods that show promise for better prediction accuracy, especially with large datasets, but have disadvantages in the areas of validation, interpretability, and data quality. While highlighting the potential for future advancements such as hybrid models, real-time environmental monitoring systems, and AI tools to enhance the reliability of predictions, the review also includes a discussion on challenges, including sparse data availability, climate change effects, and the difficulty of incorporating socio-economic factors into models, particularly in under-resourced areas like Bangladesh, where the capacity to model is still limited [3].

The fisheries industry is a significant livelihood and food source for Sri Lanka. It experienced several serious issues simultaneously during 2019-25, but it is not yet fully clear what impact these had on fish production and fish prices. This study aims to overcome the constraint of previous studies that studied these variables independently with a unified framework that relates the changes in weather, major disruption events, fish production and prices. The framework integrates these climate lag analyses, disruption estimation and forecasting into one pipeline, offering useful information for policymakers, traders and supply chain managers. Two tools used to study seasonal patterns are STL decomposition and Spearman lag correlation, used to detect delayed climate impacts on production. Interrupted Time Series (ITS) regression measures the impact of major events, and SARIMAX models are used to forecast monthly production and prices. Hotspot detection is used to detect unusual patterns. The results indicate

that marine and inland fisheries have different seasonal patterns and climate effects. The forecasting results reveal that the proposed SARIMAX models can decrease RMSE by up to 66.0%, and the MAPE values range from 4.71% to 11.31% compared to the seasonal-naïve baselines. Major disruptions had various effects, with inland production seemingly rising when marine production fell, implying some compensatory effect, but this is not conclusive without fish import data. The results of these investigations can be used to inform improved planning, including upgrading infrastructure in hazard-prone locations, enhancing cold chain facilities, and establishing early warning systems for unusual events [4].

3 METHODOLOGY

In this study, secondary quantitative time series data from January 2016 to December 2023 were used. The monthly saltwater fish harvest data for Hambantota were collected from the Sri Lankan Ministry of Fisheries. Figure 1 displays a significant downward trend in the fish harvest. The trend was tested by the Mann-Kendall test [5], and the Mann-Kendall seasonal test [6], and the Kruskal-Wallis test and the Friedman test were used to assess seasonality. The Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test, the augmented Dickey-Fuller (ADF) test, and the Phillips-Perron (PP) test were used to check stationarity.

The data set is split into two portions: the first 80% of the data set for training, and the last 20% for model evaluation. The pre-processed series were used to fit time series forecasting models: Seasonal Autoregressive Integrated Moving Average (SARIMA) models, with the best models selected by the Akaike Information Criterion (AIC) of the candidate models from the ACF and PACF plots; Holt-Winters exponential smoothing model with an additive trend and additive seasonal component was fitted with log transformation [7], Box-Cox, and Reciprocal transformation (Special Case of the Box-Cox Transformation: $\lambda = -1$), Square-root (Special Case of the Box-Cox Transformation: $\lambda = 0.5$) [8], cube-root transformation [9], as well as standardization and normalization [10], were applied directly to the pre-processed series to train the model. The accuracy of the forecasts was evaluated on a held-out test period by calculating the root mean square error (RMSE), mean absolute error (MAE), and mean absolute percentage error (MAPE), with a smaller value being better.

4 RESULTS AND DISCUSSION

The time series plot of fish harvest in Hambantota clearly showed a long-term trend and a periodic annual cycle, as the data fluctuated monthly over the period 2016-2023. This was confirmed statistically with the Mann-Kendall test, which ruled out the null hypothesis of no trend ($p < 0.01$), and the Mann-Kendall seasonal test ($p = 0.005$), Kruskal-Wallis test ($p = 0.028$), and the Friedman test collectively indicated significant seasonality. Thus, to eliminate the trend and the seasonality, the first difference and the seasonal differencing were applied. The detrended and de-seasonalized series was tested for stationarity. The series was concluded as a stationary series using the unit root tests and hence used for subsequent modelling. The fitted SARIMA model ($ARIMA(1,1,2)(2,0,0)_{[12]}$) and the Holt-Winters model with several transformations were assessed using the performance of the de-transformed series on the testing set (Table 1). The SARIMA residuals showed no significant autocorrelation, non-normality, or conditional heteroscedasticity, with Ljung–Box ($p = 0.08$), Jarque–Bera ($p = 0.24$), and ARCH-LM ($p = 0.17$) tests, respectively.

Table 1. Model performance on testing set

Model	Transformation	RMSE	MAE	MAPE
Sarima	-	711.26	596.56	23.10 %
Holt-Winters	-	807.92	671.80	25.92%
	log	707.62	535.84	18.38%
	Box-Cox	862.17	712.98	28.05%
	Reciprocal	723.86	512.86	16.60%
	Square-root	714.83	570.36	20.51%
	Cube-Root	706.77	554.38	19.60%
	Standardization	812.23	675.00	26.01%
	Normalization	812.22	675.00	26.00%

Based on the diagnostic checks, the Holt-Winters model seems to be a good fit. The Ljung–Box test revealed no significant residual autocorrelation (p-value = 0.180), which indicates that the residuals were close to being independent. The residual ACF plot

(Figure 3) showed that no further serial dependence occurred, as all autocorrelations were within the 95% confidence limits. Moreover, the residual versus the fitted values graph revealed that the residuals were randomly scattered around zero with no definite trend, suggesting that the model assumptions are reasonably fulfilled (Figure 4). In general, these diagnostic tests indicate that the Holt-Winters model is suitable for forecasting this time series.

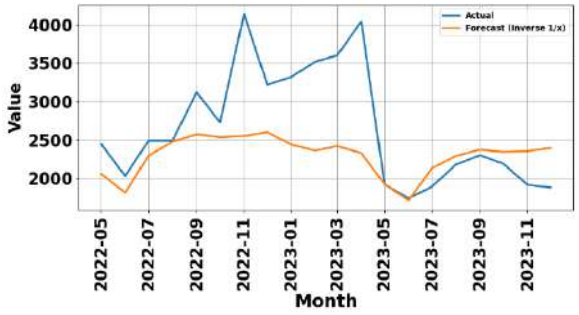


Figure 2. Actual vs fitted series on testing set

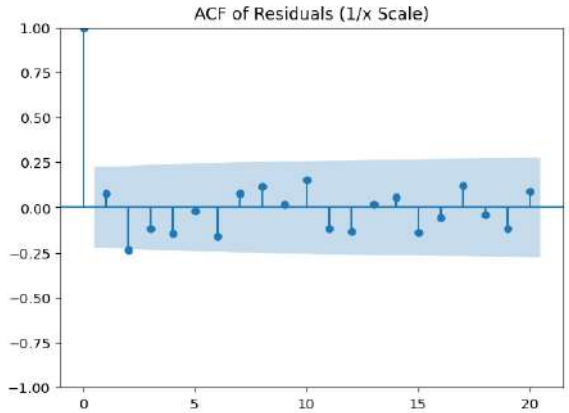


Figure 3. Autocorrelation function of residuals

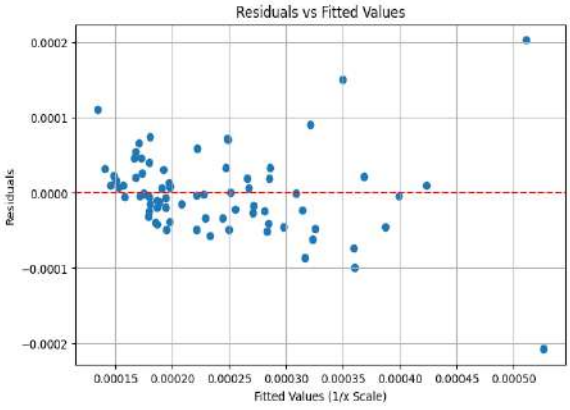


Figure 4. Residuals vs fitted plot

The results presented in Table 1 confirm that traditional time series models are very accurate when variance-stabilizing transformations are used. $ARIMA(1,1,2)(2,0,0)_{12}$ model was successful in capturing the underlying seasonal structure of the data and provided an MAPE of 23.10%. The Holt-Winters exponential smoothing models, however, performed better than the SARIMA framework with certain data transformations. The best performance was obtained with the Holt-Winters model with a Reciprocal $1/x$ transformation (Figure 2). This method gave the maximum level of accuracy in each of the key metrics and the minimum MAPE (16.60%) and MAE (512.86). The Log transformation also resulted in a very good performance with an MAPE of 18.38%, coming in second place. On the other hand, other techniques like baseline Holt-Winters (MAPE 25.92%) and standardization/normalization did not improve the base model. The SARIMA model is also better than that model. Overall, Holt-Winters models with transformations have captured the actual testing series to a greater extent than SARIMA models. Especially with log, reciprocal, and cube root transformations. The models that are usually used to model time series, such as SARIMA or Holt-Winters, are parametric models that naturally have trouble with an exogenous factor that has not been anticipated. And the special case is that there is no difference between Holt-Winters model performance with standardized or normalized data. That is a unique finding in this study.

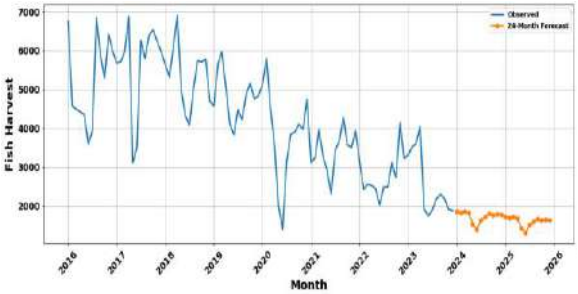


Figure 5. Two-year prediction of fish harvest in Hambantota

According to the two-year prediction of the selected model for forecasting (Holt-Winters model with a Reciprocal $(\frac{1}{x})$ transformation), future forecasts will decrease by less than 2000 (MT) monthly.

5 CONCLUSION

This study was a comprehensive comparative analysis of time-series forecasting models to forecast the fish harvest in Hambanto-

ta (Sri Lanka) on a monthly level. This study compares traditional linear architectures to different techniques in data transformation, resulting in the importance of variance stabilization for modelling highly volatile ecological and economic commodities. Empirical Results: The empirical results indicate that the Holt-Winters exponential smoothing model combined with the reciprocal transformation yields the most accurate and reliable forecasts. The SARIMA model also has better performance than the baseline Holt-Winters model without any transformations. In this study, a key finding is that traditional linear scaling techniques, such as Z-score standardization and Min-Max normalization, do not address the basic statistical issues that are inherent in fish harvest data.

The two methods showed results that were virtually the same as the baseline Holt-Winters model. This shows that the data is not just scale differences, but that of heteroscedasticity (non-constant variance over time). This variable was successfully stabilized with non-linear transformations, in this case, reciprocal and logarithmic transformations. In this way, they were able to avoid large seasonal variations influencing the long-term trend components of the models. The Reciprocal Holt-Winters model provides a useful forecasting tool for fisheries management, regional cooperative planning, and supply chain logistics in Hambantota. For fisheries management, regional cooperative planning, and logistics of supply chains, the Reciprocal Holt-Winters model is a valuable tool to predict. Make more precise predictions of harvests, allowing local government and commercial interests to predict periods of extreme supply shortage and avoid market shortages. Improve the cold storage system and distribution system during peak harvest seasons. Propose pricing stabilization policies based on evidence to safeguard local fishing communities' livelihoods. The optimized Reciprocal Holt-Winters model is a good model, but it has a major limitation that it is univariate and only uses harvest patterns from the past.

In the two years ahead, fish harvest is projected to be more or less the same, without major seasonal increases or decreases in fish production in Hambantota. On the economic development side, this means that the fisheries industry could be a steady contributor to regional economic development, but would not be able to make significant contributions without specific measures like sustainable fisheries management, technological improvements, and infrastructure development, because forecasting highlights that the fish production will be at a very low level when compared to previous years. The stable forecast offers a solid platform for budgeting, financial planning, cash flow management, and cost control in accounting and finance, though the production growth may be limited, and businesses should target operational efficiency to boost profitability. The forecast also underscores the potential of predictive models to guide strategic decision-making in the business analytics context, and the need for a better understanding of other factors like climate conditions, market demand, fuel prices, and fishing regulations to boost forecast accuracy. The expected stability enables organizations to fine-tune their production planning, staffing, equipment use, and maintenance plans without having to invest in expanding capacity and helps to promote value-added processing and waste minimization to maximize returns from operations and manufacturing. So, it can be concluded that the use of these kinds of models in this fishing industry will directly help to identify patterns and mitigate risks. In conclusion, the outlook for the next two years indicates that stakeholders should focus on enhancing production efficiency, optimizing costs, and implementing sustainable practices rather than relying on substantial production increases. As future work, performing this modelling for all other fourteen locations will be very useful for sustainable business planning in the saltwater fishing industry in Sri Lanka. And also, future research should focus on capturing the variance that is not explained by these models, as well as anomaly handling, such as the COVID-19 pandemic (2020) and the X-Press Pearl disaster (2022), in these fish-harvest data.

ACKNOWLEDGEMENT

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Investigating UI Micro-Interactions as a UX Innovation for User Emotion and Digital Product Competitiveness

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ABSTRACT: One of the major challenges in modern UX design is that many digital products are functionally effective but do not always create emotionally engaging experiences. Small UI micro-interactions, such as notifications, animations, and feedback responses, are commonly used to enhance user interaction. However, limited research has examined their influence on user emotion in everyday digital environments. This study investigated the relationship between UI micro-interactions and users' emotional experiences using a structured Likert-scale questionnaire with 300 participants. The responses were analyzed using descriptive analysis, reliability analysis, correlation analysis, regression analysis, and ANOVA. The findings revealed significant positive relationships between UI micro-interactions and user emotion, with toggle switches showing the strongest association. Confidence was identified as a significant predictor of core user emotion. This study contributes evidence-based UX design guidelines for creating more engaging, user-centered, and emotionally supportive digital interfaces.

Keywords: UX innovation, Emotion, UX design, Micro-interactions, Human computer interaction

1 INTRODUCTION

Digital interfaces have gone beyond mere efficiency and rapidity of task completion. In the digital world, not only is the usability of an interface important, but the type of experience it provides to the user is too. With mobile and Web applications growing in sophistication, minor UI micro-interactions are increasingly part of Web design. Hover effects, loading indicators, animated transitions and feedback cues can influence the nature of an interaction often making it feel smoother, more engaging, comforting and satisfying when they are done well [2], [8], [9]. This topic is academically relevant because it relates to user experience design and emotional experience in HCI, which is becoming more relevant with the increasing user-centric approach of digital products [2], [8]. It is also practically important as many digital products have similar functions and similar efficiency, but many users prefer some interfaces over others because they feel more natural, pleasant or emotionally supportive [2], [9].

While previous research has investigated aspects of usability, aesthetics, animation, feedback, and emotional design, the current knowledge is fragmented across different interface components and research settings [1] [3] [5] [6] [7]. Most of the existing work is about progress indicators, animations, loading screens, or notifier messages, and mostly studies the usability aspects of the progress or the perceived speed or the visual effect of the animation, but not user emotion itself. Therefore, there is still a lack of knowledge about how various subtle UI micro-interactions affect users emotionally in real world digital environments and what emotional state is most appropriate to be meas-

ured [3] [4] [5] [6]. This indicates a clear need for a more focused study. The purpose of this research is therefore to examine the effect of subtle UI features on the emotions of the users in the digital interaction process, to identify the subtle UI features that have the greatest impact on the emotions of the users, and to identify the key factors that can be used to measure the user's emotion in digital environments [3], [4], [5].

1.1 *Objectives*

RO1: To identify key UI micro-interactions that affect user experience

RO2: To determine the main factors that can be used to measure users' emotions in digital interactions.

RO3: To examine how subtle UI micro-interactions contribute to positive emotional responses during user interaction.

RO4: To develop a set of design guidelines for creating subtle micro-interactions that positively influence user emotion

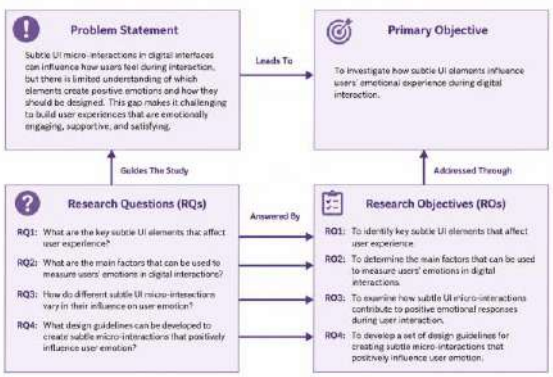


Figure 1. Objective mapping diagram

2 METHODOLOGY

2.1 *Research Problem*

This study employed a research design that was created to address a lack of understanding of the role UI micro-interactions play in the emotional experiences of users of digital interactions. Current studies tend to look at usability, performance and at isolated pieces of the UI elements, but not at the emotional impact of a multitude of micro-interactions in daily life in digital environments [3], [5], [6]. Accordingly, the relationship between UI micro-interactions and user emotion are explored in this study. This research focuses on two constructs: UI micro-interactions and user emotions. The six UI micro-interactions that have been chosen include: button hover effect, progress indicator, toggle switch, reaction animation, checkboxes and notification pop-up messages; they are selected based on the UX and HCI literature [3], [5], [7]. Six dimensions were used to measure user emotion – comfort, satisfaction, enjoyability, engagement, confidence and clarity [4], [8].

2.2 *Research Design*

The research design used in this study was a quantitative survey method that aimed to measure the relationship between UI micro-interactions and emotional experience of users [3], [4]. A structured questionnaire with a 5-point Likert scale was used to gather the data from 300 undergraduate students who use mobile and web applications. Data collected were cleaned, coded and analyzed with descriptive and inferential statistical analysis. The descriptive analysis was used to find the pattern of responses, and reliability analysis was performed using Cronbach's alpha to determine the consistency of measurement [4]. Correlation analysis was used to explore the relationship between UI micro-interactions, emotional factors and overall user emotion. Multiple regression analysis was used to establish the significant predictors of core user emotion, and ANOVA was used to check if the various UI micro-interactions elicited significantly different emotional responses. This methodological approach gives evidence-based data about the emotional effect of UI micro-interactions, and helps in building the evidence-based UX design guidelines to make more engaging and user-centered digital interfaces [3], [8].

2.3 *Research Questions*

RQ1: What are the subtle UI elements that influence user experience?

RQ2: What are the main factors that can be used to measure users' emotions in digital interactions?

RQ3: How do different subtle UI micro-interactions vary in their influence on user emotion?

RQ4: What design guidelines can be developed to create subtle micro-interactions that positively influence user emotion?

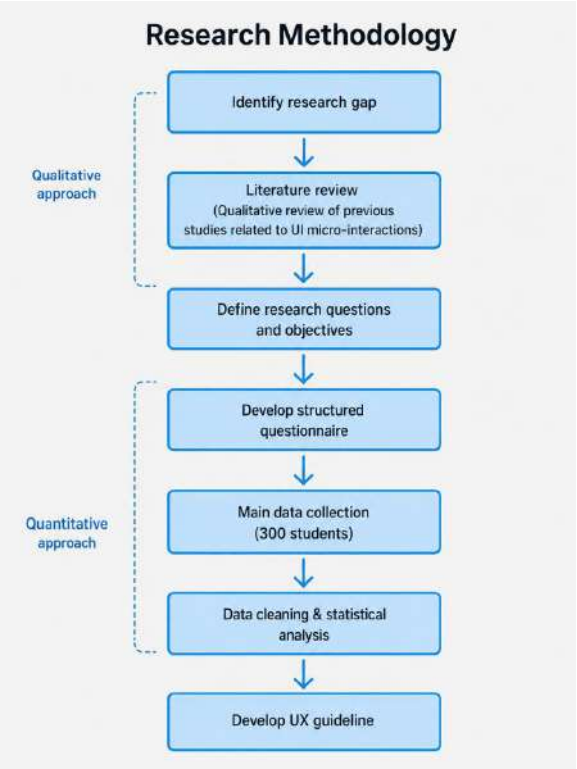


Figure 2. Methodology diagram

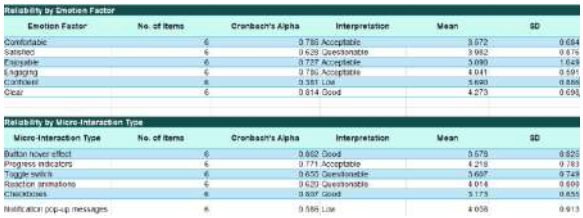
Table 1. Materials and tools

Item	Description	Purpose
Questionnaire	Structured survey with Likert-scale items	To collect data on subtle UI micro-interactions and user emotion
Participants	300 undergraduate students	To provide the main survey responses
Online Survey Tool	Google Forms	To distribute and collect questionnaire responses
Spreadsheet Software	Microsoft Excel	To clean, code, and organize data
Analysis Tool	Jamovi Software	Used for statistical analysis.

3 RESULTS

There were 300 respondents in all. The demographic profile revealed a fairly even gender balance with 55.7% of the respondent's male and 44.3% female. With regards to age, 96.7% of the respondents fall within the 25-34 age group, with only 3.3% in the 18-24 age group. Further results showed that the participants were significantly active users: 99% said that they use mobile or web applications daily. This implies that the chosen sample was a good one to explore micro-interactions within the UI in a digital context.

The reliability analysis confirmed the scales applied in the study were suitable and internally reliable. The Overall User Emotion Scale had a Cronbach's alpha of 0.911, and the Core Emotion Scale had a Cronbach's alpha of 0.888, both of which are considered to have excellent reliability. The scale of confidence + clarity also achieved a relatively good level of reliability, with a Cronbach's alpha of 0.769. These results suggest that the questionnaire was reliable, and that the obtained responses were adequate for further statistical analysis.


Reliability by Emotion Factor

Emotion Factor	No. of Items	Cronbach's Alpha	Interpretation	Mean	SD
Comfortable	6	0.780	Acceptable	3.672	0.684
Satisfied	6	0.629	Questionable	3.952	0.676
Enjoyable	6	0.727	Acceptable	3.990	1.649
Engaging	6	0.780	Acceptable	4.041	0.591
Confident	6	0.381	Low	3.690	0.886
Clear	6	0.814	Good	4.273	0.695

Reliability by Micro-Interaction Type

Micro-Interaction Type	No. of Items	Cronbach's Alpha	Interpretation	Mean	SD
Button hover effect	6	0.862	Good	3.578	0.825
Progress indicators	6	0.771	Acceptable	4.218	0.783
Toggle switch	6	0.655	Questionable	3.697	0.749
Reaction animations	6	0.620	Questionable	4.014	0.609
Checkboxes	6	0.807	Good	3.173	0.855
Notification pop-up messages	6	0.586	Low	4.038	0.913

Figure 3. Reliability analysis

All the emotional factors selected were positively and significantly correlated with the overall emotion of the users with all the correlations significant at $p<0.001$. Confidence showed the strongest relationship with overall user emotion ($r = 0.896$), followed by satisfaction ($r = 0.875$), engagement ($r = 0.795$), comfort ($r = 0.770$), enjoyability ($r = 0.706$), and clarity ($r = 0.671$). Similarly, all the types of micro-interactions selected were related to overall emotion of the user in a positive and significant manner. The toggle switch had the highest correlation ($r = 0.879$), followed by checkboxes ($r = 0.766$), reaction animations ($r = 0.758$), button hover ($r = 0.729$), notification pop-ups ($r = 0.702$) and progress indicators ($r = 0.673$). The results indicate that emotions related to the UI micro-interactions and emotional factors are strongly related to the users' emotional experience.

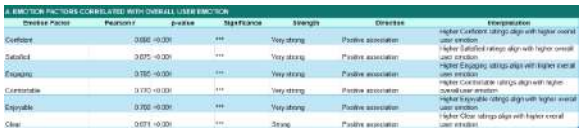


Figure 4. Correlation analysis

The regression further revealed that the model accounted for 69.5% of the variation of core user emotion, with R^2 value of 0.695 and adjusted R^2 value of 0.693. Confidence was also a strong predictor, and statistically significant ($\beta = 0.784$, $p < 0.001$), of core user emotion, while clarity was not ($\beta = 0.015$, $p = 0.5786$). The ANOVA results further showed that there were statistically significant differences in the influence of the micro-interaction types on user emotion, $F(5,1495) = 541.526$, $p < 0.001$, and a large effect size (partial eta squared = 0.644). The results of the study are consistent with the study hypotheses, as they indicate that subtle UI micro-interactions do have a significant impact on the emotional experience of users, that various types of micro-interactions have different emotional impact on users, and that some emotional factors are especially salient to the prediction of overall user emotion, particularly confidence.

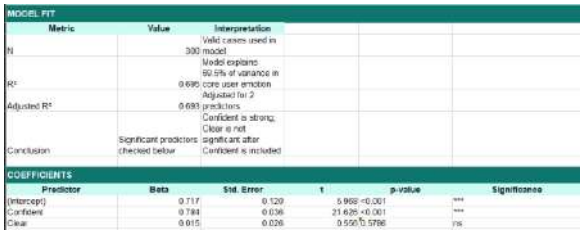


Figure 5. Regression analysis

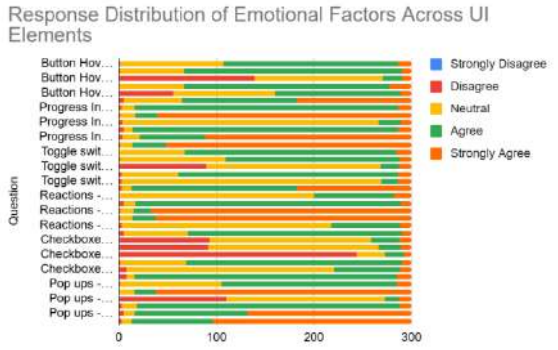


Figure 6. Response distribution of emotional factors across ui elements

4 DISCUSSION

This study's results showed that there is a significant positive correlation between UI micro-interactions and users' emotional experience of digital interaction. The overall response patterns were identified using descriptive analysis, and the results indicated that the users had positive responses to the selected micro-interactions. The reliability analysis showed that the measurement scales were reliable, and this was an indication that they could be used for further statistical analysis. The overall user emotion was found to be significantly correlated with all the micro-interactions examined, with toggle switches, checkboxes and reaction animations being the strongest, whereas progress indicators were the relatively weakest. Through regression analysis it was determined that users' confidence in the system is an important factor that affects their core user emotion, therefore, it is important for users to have a sense of confidence and control within the system when interacting with it. Also, ANOVA showed that no two UI micro-interactions have the same effect on the emotion of the user. The results in this study build on past research in UX and HCI involving the use of small interface elements to demonstrate that these elements are more than just "decorative" and can have a meaningful effect on users' emotional reactions. This research differs from previous work that mostly examined the usability, waiting time, or single UI features by presenting a comparative analysis of several UI micro-interactions and their impact on user emotions. But it should be interpreted in a limited way, including self-reported responses and a predominantly single demographic sample. The final outcome of this study is a set of evidence-based UX design guidelines that help designers create more effective and emotionally engaging micro-interactions.

5 CONCLUSION

The following is the major finding of this research: UI micro-interactions have a significant effect on the emotional experience of digital interaction. The results indicate that the various subtle UI elements have different effects on user emotions, and that some subtle UI elements lead to more positive responses from users than others, and the emotional factors of confidence, satisfaction, engagement, comfort and enjoyability are important factors influencing users' overall emotion. Thus, this study not only adds to academic knowledge but also to the

practical field of UX design, highlighting the potential of creating meaningful and positive impact through small-scale design features.

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The Impact of Artificial Intelligence and Industry 4.0 on Transforming Accounting and Auditing Practices: Evidence from a Sri Lankan Organization

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ABSTRACT: This study examines the relationship between Artificial Intelligence (AI), Industry 4.0, and employees' intention to use AI in accounting and auditing practices, focusing on employees in a selected accounting and auditing organisation in Sri Lanka. Guided by the Theory of Planned Behaviour and Fear Acquisition Theory, the study examines the relationships of AI-related anxiety, AI literacy, AI ethics, and Industry 4.0 with employees' intention to use AI. A quantitative research approach was adopted, and data were collected using structured questionnaires from 60 employees. The data were analysed using descriptive statistics, correlation analysis, and multiple regression analysis in SPSS. The findings indicate that Apply AI and Industry 4.0 were significantly and positively associated with employees' intention to use AI, while Privacy Violation Anxiety, Job Replacement Anxiety, Against Ethics Anxiety, Understand AI, Create AI, and AI Ethics did not demonstrate statistically significant relationships. The regression model explained 39.6% of the variance in employees' intention to use AI. The findings highlight the importance of practical AI application and Industry 4.0 in supporting AI use in accounting and auditing practices. The study provides practical insights for organisations seeking to facilitate AI adoption through practical AI experience, digital transformation initiatives, and employee training.

Keywords: artificial intelligence, Industry 4.0, accounting and auditing, intention to use AI, AI anxiety

1 INTRODUCTION

Artificial Intelligence (AI) has become a transformative technology that is reshaping business operations in the digital era [1]. The integration of AI has shifted many traditional, human-dependent processes towards automation, improving efficiency and productivity across organisational functions [1]. Business areas such as accounting, production, marketing, and supply chain management increasingly utilise AI applications to enhance performance and maintain competitiveness [2]. For example, AI supports data entry and analysis in accounting, improves production speed and quality through AI-driven machinery, and enables demand forecasting and resource optimisation in supply chain management [2]. Consequently, AI has contributed to the emergence of smarter and more efficient working environments.

Employees are more likely to adopt Artificial Intelligence (AI) when they perceive it as useful, easy to use, and capable of improving job performance, decision-making, and productivity [3]. The perceived benefits of AI can also motivate employees by creating opportunities for career development, higher earnings, and future leadership roles. Furthermore, employees' trust in the accuracy and reliability of AI-generated information positively influences their willingness to use AI technologies [3]. Organisational culture also plays a significant role, as workplaces that encourage in-

novation, creativity, and experimentation with new technologies are more likely to foster positive attitudes and intentions towards AI adoption [4].

1.1 *Research Problem*

Artificial Intelligence (AI) has become a key driver of digital transformation across organisations worldwide, enabling improvements in efficiency, productivity, decision-making, and automation. As a core technology of Industry 4.0, AI is increasingly integrated into business operations to enhance organisational performance and maintain competitiveness [1], [2]. Despite these benefits, successful AI implementation depends not only on technological capability but also on employees' willingness to adopt and use AI technologies.

Within the accounting and auditing profession, AI has transformed routine processes such as financial reporting, fraud detection, data analysis, and audit procedures [5]. However, employees often experience concerns relating to privacy violations, job replacement, and ethical issues, while differences in AI literacy and organisational readiness may influence their intention to use AI technologies. These barriers can limit the successful implementation of AI and prevent organisations from fully realising its potential benefits [6], [7].

Although previous studies have extensively examined AI adoption, most have focused on technological acceptance, organisational performance, or AI implementation in developed countries. Limited research has simultaneously examined the influence of AI-related anxiety, AI literacy, AI ethics, and Industry 4.0 on employees' intention to use AI within the accounting and auditing profession, particularly in the Sri Lankan context. Given the increasing digital transformation of Sri Lanka's accounting and auditing sector, understanding these factors is essential for supporting successful AI adoption.

Therefore, this study addresses this research gap by examining the effect of privacy violation anxiety, job replacement anxiety, against ethics anxiety, AI literacy, AI ethics, and Industry 4.0 on employees' intention to use AI among accounting and auditing professionals in Sri Lanka. The findings are expected to contribute to the existing literature while providing practical insights for organisations seeking to enhance AI adoption and support employees during digital transformation.

1.2 *Research Objectives*

- To what extent privacy violation anxiety affect employees' intention to use AI
- To what extent job replacement anxiety affect employees' intention to use AI
- To what extent against ethics anxiety affect employees' intention to use AI
- To what extent applying AI affect employees' intention to use AI
- To what extent understanding AI affect employees' intention to use AI
- To what extent creating AI affect employees' intention to use AI
- To what extent AI ethics affect employees' intention to use AI
- To what extent industry 4.0 affect employees' intention to use AI

2 LITERATURE REVIEW

This study examines the adoption of Artificial Intelligence (AI) in accounting and auditing through relevant theoretical perspectives. Although several theories, including the Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use of Technology (UTAUT), Diffusion of Innovation Theory (DOI), and others have been used to explain technology adoption, this research primarily relies on the Theory of Planned Behaviour (TPB) and Fear Acquisition Theory. These theories provide a suitable framework for understanding employees' behavioural intentions to use AI and the impact of AI-related concerns and anxieties on technology acceptance within accounting and auditing practices.

2.1 *Theory of Planned behavior*

The Theory of Planned Behaviour (TPB) explains that behavioural intention is influenced by attitudes, subjective norms, and perceived behavioural control [8]. In the context of Artificial Intelligence (AI), positive attitudes towards AI, supportive organisational environments, and confidence in using AI technologies can encourage adoption in accounting and auditing practices [9], [10]. Owing to its ability to explain technology-related behavioural intentions, TPB

provides a useful theoretical basis for understanding employees' intention to use AI. However, the theory mainly emphasises rational decision-making and may not fully capture emotional factors such as fear and anxiety associated with emerging technologies [11], [12].

2.2 *Fear Acquisition Theory*

Fear Acquisition Theory explains that individuals may develop fear through direct experiences, observing others, or receiving negative information about a particular situation or technology [13]. In the context of Artificial Intelligence (AI), negative experiences, perceived risks, or concerns communicated by others may discourage employees from adopting AI systems in accounting and auditing [14], [15]. Therefore, the theory provides an appropriate framework for understanding fear-based barriers to AI adoption, although it may not fully account for organisational and technological factors that also influence adoption behaviour [16], [17].

2.2.1 *Privacy Violation Anxiety*

Privacy violation anxiety refers to the concern and discomfort individuals experience when Artificial Intelligence (AI) systems are perceived to invade personal privacy through the collection, storage, and use of personal data [18]. As AI relies heavily on large volumes of data, users often have limited control over how their information is managed, leading to concerns about data misuse, identity theft, fraud, and a lack of transparency [19]. Incidents such as the Facebook Cambridge Analytica scandal have further increased public concern regarding personal data protection [20]. To reduce privacy-related concerns, organisations should ensure transparency, implement strong security measures, and comply with appropriate regulations governing AI use [21].

H_1 – Privacy violation anxiety has an effect on the intention to use AI.

2.2.2 *Job Replacement Anxiety*

Job replacement anxiety refers to the fear that AI may replace human jobs or reduce employment opportunities, particularly as automation becomes increasingly common across industries, including accounting [18]. AI has enhanced efficiency and accuracy in tasks such as financial reporting, fraud detection, and invoice management, resulting in the automation of many routine activities traditionally performed by accountants [22]. Although large-scale workforce replacement has not yet occurred, concerns regarding future job displacement contribute to employee anxiety, job insecurity, and uncertainty about future career prospects [23].

H_2 – Job replacement anxiety has an effect on the intention to use AI.

2.2.3 *Against Ethics Anxiety*

Against ethics anxiety refers to feelings of tension, worry, and discomfort arising from concerns that AI-related decisions or actions may conflict with ethical values and standards [7]. The growing integration of AI into business and society has raised concerns regarding privacy, fairness, accountability, and biased decision-making, increasing ethical anxieties among users [24]. Such concerns may discourage individuals from adopting AI technologies despite their potential benefits for efficiency and productivity. Improving ethical awareness, education, and the implementation of appropriate ethical guidelines can help strengthen trust and support responsible AI adoption [24].

H_3 – Against ethics anxiety has an effect on the intention to use AI.

2.2.4 *Use and Apply AI*

The effective use and application of AI involve integrating AI technologies into organisational processes to improve efficiency, productivity, and decision-making [25]. Businesses increasingly utilise AI across functions such as customer service, cybersecurity, inventory management, content creation, and accounting to enhance operational performance and reduce costs [26]. Although challenges such as implementation costs, system integration, and skill shortages remain, organisations continue to invest in AI and employee training to maximise its benefits [25]. Consequently, AI enables organisations to automate routine tasks, improve decision quality, and maintain competitiveness in a rapidly evolving business environment.

H_4 – Using and applying AI has an effect on the intention to use AI.

2.2.5 *Know and Understand AI*

Knowledge and understanding of AI are increasingly important for accounting professionals as technological advancements con-

tinue to transform the profession. AI knowledge includes understanding technologies such as machine learning, robotics, and natural language processing, which support data analysis, fraud detection, transaction processing, and decision-making [27]. A strong understanding of AI can improve productivity, service quality, and fraud prevention while enhancing the quality of accounting information. Therefore, continuous development of AI-related competencies is essential for accountants to remain competitive and adapt to changing professional requirements [7].

H_5 – *Knowing and understanding AI has an effect on the intention to use AI.*

2.2.6 *Evaluate and Create AI*

The ability to evaluate and create AI involves understanding, assessing, and developing AI-driven solutions that improve organizational and professional outcomes. In accounting and auditing, AI supports advanced data analytics, automation, decision-making, and service quality improvement, leading to greater efficiency and effectiveness [28]. Evaluating AI requires consideration of its opportunities, limitations, and emerging technologies, including neural networks, fuzzy systems, genetic algorithms, and hybrid systems [28]. Furthermore, technologies such as machine learning, natural language processing, cloud computing, blockchain, and big data continue to expand the capabilities and applications of AI within organisations [29].

H_6 – *Evaluating and Creating AI has an effect on the intention to use AI.*

2.2.7 *AI Ethics*

AI ethics refers to the principles that guide the fair, transparent, accountable, and responsible use of AI technologies [30]. As AI adoption increases within accounting and auditing, ethical considerations have become essential for maintaining trust, credibility, and data integrity [31]. Core ethical principles include fairness, accountability, transparency, and data privacy, which help minimise bias and protect stakeholder interests [32]. Integrating these ethical principles into organisational practices can promote responsible AI use, strengthen public trust, and reduce risks associated with privacy violations and unfair outcomes [32].

H_7 – *AI ethics has an effect on the intention to use AI.*

2.2.8 *Industry 4.0*

Industry 4.0, also known as the Fourth Industrial Revolution, refers to the integration of advanced digital technologies to create smart and highly automated systems that improve organisational efficiency and productivity [33]. Introduced in 2011, Industry 4.0 incorporates technologies such as cyber-physical systems, the Internet of Things (IoT), cloud computing, robotics, big data, and Artificial Intelligence (AI) [34]. These technologies facilitate automation, digital integration, and enhanced operational performance, although organisations may face challenges related to implementation and adaptability [35].

H_8 – *Industry 4.0 has an effect on the intention to use AI.*

3 METHODOLOGY

This study adopted a positivist research philosophy, which emphasizes objective and measurable evidence and is appropriate for quantitative research. A deductive research approach was employed, drawing on the Theory of Planned Behaviors (TPB) and Fear Acquisition Theory as the theoretical foundations for developing and testing the research hypotheses. The study employed a quantitative survey strategy with a mono-method approach [38]. A cross-sectional research design was adopted, with data collected at a single point in time to examine employees' perceptions and intention to use Artificial Intelligence (AI).

The study focused on employees engaged in accounting and auditing activities within a selected accounting and auditing organization in Sri Lanka. A total of 60 employees, comprising 30 males and 30 females, participated in the study. Convenience sampling was employed, whereby employees who were available and willing to participate were invited to complete the questionnaire. Both accounting and auditing employees were included based on the relevance of their professional roles to the study of AI adoption.

Primary data were collected using a structured, close-ended physical questionnaire. The questionnaire was adapted from questions used in previous research studies to measure the constructs examined in this

study. The questionnaire consisted of two sections. The first section collected demographic information, while the second section measured privacy violation anxiety, job replacement anxiety, against ethics anxiety, AI literacy dimensions (Apply AI, Understand AI, and Create AI), AI ethics, Industry 4.0, and employees' intention to use AI. A five-point Likert scale was used to measure the study variables. The questionnaire was designed to be completed within approximately 10–15 minutes. Participation was voluntary, and responses were collected anonymously and treated confidentially.

The collected data were analyzed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistics were used to summaries the demographic characteristics of the respondents and the study variables. Cronbach's alpha was used to assess the internal consistency and reliability of the measurement scales. Pearson correlation analysis was conducted to examine the strength and direction of the relationships between the independent variables and employees' intention to use AI. Subsequently, multiple regression analysis was conducted to examine the relationships between the eight independent variables and employees' intention to use AI and to test the proposed hypotheses.

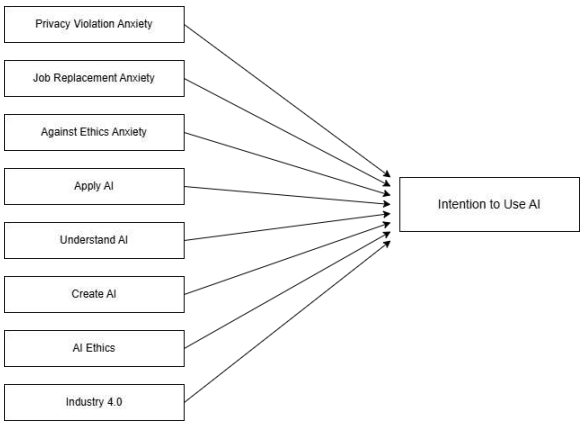


Figure 1. Conceptual framework

4 DATA ANALYSIS AND PRESENTATION

4.1 *Descriptive statistics*

A total of 60 employees participated in the study, comprising 30 males (50%) and 30 females (50%), resulting in an equal gender distribution. All questionnaires were completed and returned, providing a response rate of 100%. The age distribution indicates that the majority of respondents were between 26-35 years (31.7%), followed by those aged 18-25 years (28.3%) and 36-45 years (25.0%). Employees aged 46 years and above represented the smallest group (15.0%). Regarding educational qualifications, most respondents possessed a Bachelor's Degree (55.0%), while Advanced Level and Master's Degree holders each accounted for 16.7%. Respondents with PhD qualifications represented 6.7%, Ordinary Level qualifications represented 3.3%, and Chartered Accountant (CA) qualifications accounted for 1.7%, indicating that the sample was mostly academically qualified.

In terms of work experience, the largest proportion of respondents had between 1-5 years of experience (35.0%), followed by those with 6-10 years (26.7%) and more than 10 years (23.3%). Employees with less than one year of experience accounted for 15.0%. Furthermore, 43.3% of respondents considered Artificial Intelligence (AI) to be very important in their jobs, while 35.0% expressed a neutral view and 21.7% considered it not important. Overall, the demographic profile indicates that the study was based on a diverse and suitably qualified group of respondents for examining factors influencing the intention to use AI.

Dependent variable - Intention to use AI	Pearson value	Significance value
Privacy Violation Anxiety	0.09	0.496 > 0.05 (Not significant)
Job Replacement Anxiety	0.194	0.138 > 0.05 (Not significant)
Against Ethics Anxiety	0.064	0.625 > 0.05 (Not significant)
Apply AI	0.498	0.001 < 0.05 (Significant)
Understand AI	0.171	0.193 > 0.05 (Not significant)
Create AI	0.006	0.964 > 0.05 (Not significant)
AI Ethics	0.228	0.079 > 0.05 (Not significant)
Industry 4.0	0.414	0.001 < 0.05 (Significant)

4.2 *Reliability Analysis*

Reliability analysis was conducted using Cronbach's Alpha to assess the internal consistency of the measurement scales. As

shown in Table 1, the independent variables, namely privacy violation anxiety, job replacement anxiety, against ethics anxiety, apply AI, understand AI, create AI, AI ethics, and Industry 4.0, together with the dependent variable, intention to use AI, all recorded Cronbach's Alpha values greater than 0.70 (ranging from 0.789 to 0.888). This indicates satisfactory internal consistency and confirms that the measurement scales are reliable for subsequent statistical analyses.

Table 1. Reliability analysis

Variable	Symbol	Cronbach's Alpha value
Privacy Violation Anxiety	PVA	0.886
Job Replacement Anxiety	JRA	0.877
Against Ethics Anxiety	AEA	0.789
Apply AI	AA	0.884
Understand AI	UA	0.836
Create AI	CA	0.888
AI Ethics	AEA	0.86
Industry 4.0	I4.0	0.852
Intention to use AI	IU	0.848

4.3 *Correlation Analysis*

Pearson correlation analysis was conducted to examine the strength and direction of the relationships between the independent variables and employees' intention to use Artificial Intelligence (AI). The results indicate that Apply AI ($r = 0.498$, $p = 0.001$) and Industry 4.0 ($r = 0.414$, $p = 0.001$) have moderate positive and statistically significant relationships with the intention to use AI, as their significance values are below the 0.05 threshold. This suggests that employees with greater ability to apply AI and higher exposure to Industry 4.0 technologies are more likely to demonstrate a stronger intention to use AI.

The remaining variables showed statistically insignificant relationships with the intention to use AI. Privacy Violation Anxiety ($r = 0.090$, $p = 0.496$), Job Replacement Anxiety ($r = 0.194$, $p = 0.138$), Against Ethics Anxiety ($r = 0.064$, $p = 0.625$), Understand AI ($r = 0.171$, $p = 0.193$), Create AI ($r = 0.006$, $p = 0.964$), and AI Ethics ($r = 0.228$, $p = 0.079$) all exhibited weak positive correlations, but none were statistically significant because their p-values exceeded 0.05. Overall, the findings suggest that only Apply AI and Industry 4.0 were significantly associated with employees' intention to use AI, while the remaining variables did not demonstrate significant relationships.

Table 2. Correlation analysis

4.4 *Regression Analysis*

Regression analysis was conducted to examine the effect of the independent variables on employees' intention to use Artificial Intelligence (AI). The model summary indicates an R Square value of 0.396 and an Adjusted R Square value of 0.301, suggesting that approximately 39.6% of the variation in employees' intention to use AI is explained by the independent variables included in the model. The remaining variation may be attributed to other factors not examined in this study. Furthermore, the ANOVA results indicate that the overall regression model is statistically significant ($F = 4.175$, $p < 0.001$), confirming that the model provides a good fit for the data and is appropriate for examining the influence of the selected independent variables on employees' intention to use AI.

Table 3. Model summary

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	.629[a]	.396	.301	.65477

a. Predictors: (Constant), I4.0, JRA, CA, UA, AA, AEA, AE, PVA

b. Dependent Variable: ITUA

Table 4. ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	14.318	8	1.790	4.175	<.001[b]
Residual	21.865	51	.429		
Total	36.183	59			

a. Dependent Variable: ITUA

b. Predictors: (Constant), I4.0, JRA, CA, UA, AA, AEA, AE, PVA

Table 5. Regression analysis

	B	Std. Error	β	t	p-value
α	1.196	0.651	-	1.836	0.072
PVA	-0.140	0.135	-0.159	-1.040	0.303
JRA	0.229	0.130	0.250	1.763	0.084
AEA	-0.149	0.155	-0.141	-0.957	0.343
AA	0.561	0.143	0.516	3.924	<0.001
UA	-0.064	0.138	-0.059	-0.464	0.645
CA	-0.081	0.098	-0.101	-0.824	0.414
AE	-0.123	0.151	-0.119	-0.811	0.421
I4.0	0.419	0.151	0.366	2.773	0.008

4.5 *Discussion of Regression Findings*

Multiple regression analysis was conducted to examine the relationships between Privacy Violation Anxiety (PVA), Job Replacement Anxiety (JRA), Against Ethics Anxiety (AEA), Apply AI (AA), Understand AI (UA), Create AI (CA), AI Ethics (AE), and Industry 4.0 (I4.0) and employees' intention to use Artificial Intelligence (AI). Intention to Use AI was considered the dependent variable, while the eight identified factors were included as independent variables in the regression model.

The model summary indicates a moderate positive correlation between the eight independent variables and employees' Intention to Use AI ($R = 0.629$). The coefficient of determination (R^2) was 0.396, indicating that the eight independent variables collectively explained 39.6% of the variance in employees' Intention to Use AI. The adjusted R^2 was 0.301, indicating that 30.1% of the variance in Intention to Use AI was explained by the independent variables after adjusting for the number of variables included in the model.

The ANOVA results indicate that the overall regression model was statistically significant, $F(8, 51) = 4.175$, $p < 0.001$. This indicates that the eight independent variables, when considered collectively, demonstrated a statistically significant relationship with employees' Intention to Use AI. Therefore, the regression model provides statistical evidence that at least one of the independent variables is significantly associated with Intention to Use AI.

The regression coefficients indicate that Apply AI demonstrated the strongest statistically significant positive relationship with Intention to Use AI ($\beta = 0.516$, $t = 3.924$, $p < 0.001$). This indicates that higher levels of practical application of AI were associated with higher levels of Intention to Use AI, while controlling for the other variables included in the regression model. Industry 4.0 also demonstrated a statistically significant positive relationship with Intention to Use AI ($\beta = 0.366$, $t = 2.773$, $p = 0.008$). Therefore, Apply AI and Industry 4.0 were the only variables that demonstrated statistically significant positive relationships with employees' Intention to Use AI.

In contrast, Privacy Violation Anxiety did not demonstrate a statistically significant relationship with Intention to Use AI ($\beta = -0.159$, $t = -1.040$, $p = 0.303$). Similarly, Job Replacement Anxiety was not statistically significant ($\beta = 0.250$, $t = 1.763$, $p = 0.084$), although its coefficient was positive. Against Ethics Anxiety also did not demonstrate a statistically significant relationship with Intention to Use AI ($\beta = -0.141$, $t = -0.957$, $p = 0.343$). Furthermore, Understand AI ($\beta = -0.059$, $t = -0.464$, $p = 0.645$), Create AI ($\beta = -0.101$, $t = -0.824$, $p = 0.414$), and AI Ethics ($\beta = -0.119$, $t = -0.811$, $p = 0.421$) did not demonstrate statistically significant relationships with Intention to Use AI.

Overall, the regression analysis indicates that Apply AI and Industry 4.0 were the only variables that demonstrated statistically significant relationships with employees' Intention to Use AI among the eight factors examined. Apply AI had the largest standardized beta coefficient ($\beta = 0.516$), followed by Industry 4.0 ($\beta = 0.366$). The remaining six variables did not reach the 5% significance level. These findings suggest that practical engagement with AI and the broader Industry 4.0 environment were more strongly associated with employees' Intention to Use AI within the sampled organization than the examined anxiety, AI literacy, and AI ethics dimensions.

5 CONCLUSION

This research aimed to examine the relationships between artificial intelligence (AI), Industry 4.0, and the intention to use AI in accounting and auditing practices. Data were collected from 60 employees within a selected accounting and auditing organisation in Sri Lanka, and the hypotheses were tested using statistical methods in SPSS.

The findings revealed that the hypotheses relating to "Apply AI" (H4) and "Industry 4.0" (H8) were accepted, as both demonstrated statistically significant positive relationships with employees' Intention to Use AI. This suggests that practical application of AI and exposure to Industry 4.0 are associated with stronger intention to use AI among the surveyed employees.

On the other hand, the hypotheses related to "Privacy Violation Anxiety" (H1), "Job Replacement Anxiety" (H2), "Against Ethics Anxiety" (H3), "Understand AI" (H5), "Create AI" (H6), and "AI Ethics" (H7) were rejected, as they did not demonstrate statistically significant relationships with employees' Intention to Use AI. Therefore, these factors did not show statistically significant relationships with Intention to Use AI among the surveyed employees.

In conclusion, within the selected organisation, practical application of AI and Industry 4.0 were significantly associated with employees' Intention to Use AI, while the other factors examined did not show statistically significant relationships. The findings highlight the importance of practical AI application and Industry 4.0 in supporting the use of AI in accounting and auditing practices.

The study provides important practical implications for accounting firms and other organisations undergoing digital transformation. Rather than focusing solely on reducing employees' concerns about AI, organisations should prioritise creating opportunities for employees to gain practical experience with AI technologies, invest in Industry 4.0 initiatives, and provide continuous training that enables employees to integrate AI into their daily work. Such initiatives can strengthen employees' confidence, improve organisational efficiency, and support the effective implementation of AI-driven accounting and auditing practices.

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Agglomeration Strategy towards Rural Resilience: Perspectives of Homestay Tourism Operators in Sri Lanka as a Developing Tourism Economy

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ABSTRACT: Rural homestay operators are vital to Sri Lanka's tourism-driven socio-economic development. However, remain disproportionately vulnerable to economic and environmental shocks due to limited resources, inadequate training, and weak institutional support. This qualitative study examines how agglomeration strategies (AS) can strengthen rural resilience (RR) addressing the limitations and opportunities of homestay operators in the Kandy District. Data was collected from 15 homestay tour operators registered in SLTDA using semi-structured interviews using purposive sampling method and analyzed through content analysis. Findings reveal that collaboration is constrained by relational, resource-based, and regulatory barriers, including communication difficulties, competition arising from inconsistent service standards, lack of a common vision, and complicated licensing procedures. However, significant opportunities emerge through mutual assistance, knowledge sharing, joint packages, and shared marketing and transportation, which enhance networking, reputation, and skill development. The study concludes that cooperative governance frameworks, capacity-building, and integration of homestay networks into regional tourism strategies are essential for transitioning operators from vulnerability to systemic resilience, offering practical implications for policymakers supporting and empower the Sri Lanka's rural tourism MSME sector.

Keywords: Agglomeration Strategy, Rural Resilience, Homestay Tour Operators, Developing Tourism Economies, Sri Lanka

1 INTRODUCTION

Tourism stands as one of the world's most dynamic and fastest-growing industries serving as a critical engine for socio-economic advancement, employment, and cross-cultural exchange. In Sri Lanka, tourism is the country's third-largest source of foreign exchange contributing 4.9% to the national GDP and providing direct or indirect employment to over 388,000 individuals. However, this growth remains inherently fragile over the past two decades, as Sri Lanka's tourism sector has faced recurring disruptions which have severely undermined resilience. These challenges range from the three-decade civil war that concluded in 2009, to the 2019 Easter Sunday terrorist attacks, the global COVID-19 pandemic and natural disasters. Such volatile history underscores the urgent necessity of developing tourism systems capable of handling external shocks and resisting disturbances without compromising the stability of local communities or the livelihoods of who depend on the tourism industry where majority

represents the MSMEs (Micro, Small, Medium Enterprises)

In this context, homestay tourism has emerged as a key mechanism for socio-economic revitalization and to ensure sustainability of rural areas. By enabling visitors to reside with host families, homestays concept provide authentic cultural experiences while routing direct economic benefits to local households[1]. Although the concept remained underdeveloped during the crisis situations in past years, the sector has expanded significantly since 2009, reaching 1,112 registered tourism business by 2026 [2]. Despite this potential, homestay operators confront multifaceted economic and environmental challenges including inadequate infrastructure, limited market visibility, and high vulnerability to natural disasters and trade disputes.

To mitigate these risks the agglomeration strategy geographically proximate the firms cluster to share resources, foster collaboration, and exchange knowledge has emerged as a strategic solution for small-scale operators to overcome challenges [3]. By examining the perspectives of homestay operators in the Kandy District Sri Lanka, this study explores how agglomeration strategies influence rural resilience. Specifically, exploring the opportunities and limitations associated with implementing agglomeration strategies in the unique socio-economic landscape of Sri Lanka. Hence, the study aims to contribute to a deeper understanding of resilience-building strategies and providing actionable insights for sustainable tourism development in rural communities while ensuring the resilience.

2 LITERATURE REVIEW

2.1 *Conceptualizing Tourism Resilience*

Tourism resilience has increasingly become a critical imperative for businesses, communities and destinations facing systemic shocks[4].While resilience was historically conceptualized as "bouncing back" from adversity, and contemporary literature emphasizes it as "bouncing forward" which is a transformative capacity that enables organizations absorb shocks and adapt to improve capabilities for long-term development. This evolutionary perspective in resilience reflects as a dynamic process rather than a static state where tourism systems continuously reorganize to maintain business functionalities in the face of uncertainty.

The explanation on resilience agility which is a managerial approach encompassing operational, network and destination levels highlights the need for a comprehensive strategy to identify and bridge competence gaps in the business [5]. The approach is essential for practitioners to incorporate both forced and voluntary transformations to ensure that tourism systems remain resilient and sustainable in the "new normal" situations. The adaptive capacity is critical for rural and community-based tourism to mitigate the vulnerabilities inherent in tourism-dependent economies which are susceptible to economic, environmental, and geopolitical disruptions.

2.2 *Challenges in Rural and Homestay Tourism*

Small tourism enterprises including homestay operators play a vital role in rural development by preserving cultural heritage of the destination, supporting local livelihoods and enhancing social cohesion [6]. These enterprises are particularly prone to crises because they operate with limited financial resources, inadequate formal training, and a high dependence on external demand than stick to business strategies [7].In the Sri Lankan context, the tourism industry has faced recurring disruptions which have severely undermined the resilience of small-scale operators which lead to fluctuations in the economic gains. The home-based businesses are operating solely on convenience and particularly for women entrepreneurs with lack dedicated premises and formal institutional support are highly vulnerable to shocks. Consequently, maintaining the continuity and viability of these small-scale operations necessitates strategic interventions that move beyond mere survival along with new strategic support [8].

2.3 *Agglomeration Strategies as Resilience Mechanisms*

To overcome the constraints inherent in small-scale rural tourism, the literature emphasizes the strategic importance of agglomeration for clustering of geographically proximate firms in offering complementary services. By fostering functional connectivi-

ty, operators can leverage synergistic effects, pool resources, and share knowledge for creating effective "homestay-rural" community network[9]. This clustering mechanism not only promotes efficiency but also enhances collective competitiveness by enabling consensus in strategic decision-making and facilitating risk-sharing among stakeholders [10].

Agglomeration strategies go beyond simple co-location which involved the creation of integrated visitor itineraries and the consolidation of resilience [9]. As evidenced in various contexts, such partnerships between homestays, local residents, and village collectives foster sustainable resilience which enabling stakeholders to capitalize on their respective resource advantages[11]. Furthermore, integrating sustainability and community social responsibility into the business models, operators can signal stability and foster trust among tourists which is essential for long-term viability. The public sector plays a pivotal role in these frameworks in providing the governance necessary to institutionalize cooperative efforts and overcome the fragmented approaches often seen in rural destination management.

2.4 *Empirical Gaps in Rural Tourism Resilience*

Despite the growing recognition of agglomeration as a resilience-building there is a significant empirical gaps remain in the literature in different context. While research from developed nations, such as China demonstrates how localized practices of rural tourism service providers can enhance cross-scalar resilience[12]. The application of these strategies in rural regions of developing countries remains limited. Existing studies have frequently focused on disaster management in to destination level than community-based tourism focused on rural areas. This has created a gap in understanding how small-scale operators in specific contexts such as the Kandy District of Sri Lanka can effectively implement agglomeration to foster tourism resilience.

Furthermore, although policymakers have identified resilient tourism as a core priority, there is a lack of context-specific analysis on understanding the opportunities and limitations associated with implementing these strategies at a local level. Given that the majority of agglomeration research is centered on urban settings in developed nations, rural regions in developing countries like Sri Lanka remain relatively understudied. This study aims to address this knowledge gap by exploring how agglomeration strategies influence rural resilience within the homestay sector, thereby contributing to a deeper understanding of sustainable tourism development in volatile contexts [12]

3 METHODOLOGY

This study employed an interpretivist qualitative case study design to explore the opportunities and challenges of adopting agglomeration strategies (AS) for rural resilience (RR) among homestay operators in Kandy District. Given the absence of a centralized operator registry, the study utilized a purposive sampling to select 15 operators with a minimum of five years' industry experience ensuring information-rich case. Interviews continued until thematic saturation was reached. Data were gathered through semi-structured face-to-face interviews in duration of 30 minutes conducted in Sinhala and English based on participant preference. The interviews were audio-recorded with informed consent, transcribed verbatim and translated where necessary. Data were analyzed using inductive thematic content analysis following six-phase framework.

4 RESULTS AND DISCUSSION

4.1 *Challenges and opportunities caused by homestay tourism operators when implementing an agglomeration strategy to enhance rural resilience*

4.1.1 *Challenges*

Challenges initially took place in some main aspects: communication barriers, competition, Lack of common Vision, and regulatory restrictions.

4.1.1.1 Communication Barriers

"Ummm..... Yes, one challenge I see here is that few people share the same opinion. Most homestays here are done by people from other regions. That's why there is a lack of communication."

(Respondent 01: Personal Communication - 2026)

The interviewee highlighted that among the key issues facing homestay operators is the absence of a common vision among stakeholders. The interviewee highlighted that the majority of the homestay business entities operating in the region have owners with origins from elsewhere. External involvement has led to limited local harmony as well as creating barriers towards effective communication. It therefore follows that the absence of a common vision constrains collaboration and reduces collective action capabilities among the operators.[13]

"We... face many challenges in terms of communication."

(Respondent 05: Personal Communication - 2026)

This interviewee highlighted communication issues which lead inability to maintain stable and meaningful relationships has curtailed cooperative network evolution. Also, the interviewee highlighted that the absence of a coordinated communication mechanism has made joint event organization particularly challenging. This lack of coordination negates collective marketing opportunities, resource sharing, and collaboration of community-based tourism endeavors.

4.1.1.2 Competition

"Some operators dislike our rates and, rather than referring guests to cheaper homestays, offer extra perks or discounts to win bookings themselves. This competitive mindset makes forming alliances or pooling resources difficult"

(Respondent 07: Personal Communication - 2026)

The rate differences among homestay operators, where differences in rates lead to dissatisfaction and rivalry. Instead of collaborating through the sharing of customers between homestays, some operators attempt to entice with discounts or additional services. This behavior reduces the likelihood of achieving alliances or pool resources, thereby preventing collective benefit.

"Sometimes, even though some homestays have a large number of guests, accommodation operators are hesitant to refer them to other nearby"

(Respondent 05: Personal Communication - 2026)

From this viewpoint, competition occurs due to the fact that operators do not wish to refer excess guests to close-by homestays. Despite their limited accommodation, some operators prefer retaining potential clients rather than promoting cooperation, and this violates cooperative possibility and trust in the business.

"Ummm.....Also, the goals of other homestay operators are a bit different from ours, so some operators often see each other as competitors rather than partners."

(Respondent 01: Personal Communication - 2026).

4.1.1.3 Lack of a Common Vision

"The lack of a common goal is one of the main obstacles and put more emphasis on long-term sustainability or cultural preservation, and others maximizing short-term profitability."

(Respondent 06: Personal Communication - 2026)

This response identifies the absence of shared vision as a serious impediment to collective action among homestay operators. Divergent priorities, such as the preference for sustainability against immediate profitability, lead to fragmented efforts. Promotional campaigns, resource utilization, and service standards become erratic, thereby diluting the overall effect of collective effort [9]

"Ummm... There is no common goal among the homestay operators here now. This is leading to disorganized efforts."

(Respondent 02: Personal Communication - 2026)

4.1.1.4 Complicated Licensing and Regulations

"Aaaa.... there are different legal standards here. Then many homestay operators here struggle to comply with the legal standards in the city."

(Respondent 01: Personal Communication - 2026)

This respondent points to the challenge of rural and urban disparity in terms of legal standards. Homestay operators of rural Kandy are challenged with adapting to city-focused regulatory requirements, which limits their ability to participate in collective or collaborative actions fully.

"Homestays in rural difficult time obtaining business permits than those in central Kandy, which could limit their capacity to work together on cooperative homestay projects."

(Respondent 08: Personal Communication - 2026)

Accordingly, the homestay operators provided comparable answers regarding the challenges caused by homestay tourism operators when implementing an AS to enhance RR. Respondents mentioned that Resistance to Change, Lack of Trust, Geographical Distance, and Differences in Service Standards are main considerations.

4.1.2 *Opportunity*

4.1.2.1 Helping Each Other

“ “When homestays get extra guests, they refer them to us. Hotels also contact us to arrange accommodation for tour guides, and we coordinate with local operators.”

(Respondent 01: Personal Communication - 2026)

This identifies the cooperative practices among homestay operators and local hotels in managing excess demand. As guest numbers increase, additional visitors are referred to other homestays or on-sold to tour operators, exemplifying the cooperative system that promotes business opportunities for more than one stakeholder.

“If the other guests increase, they will contact us and give us those guests.”

(Respondent 02: Personal Communication - 2026)

This finding also supports the cooperative guest-sharing behavior. Operators readily transfer surplus guests to others and exhibit mutual trust and interdependence, that they subscribe to a cooperative relationship in the homestay business[5].

4.1.2.2 Learning from each other

“Some operators may know how to decorate rooms beautifully, while another may know how to use social media to attract guests. This is where sharing tips comes in.”

(Respondent 03: Personal Communication - 2026)

This response identifies the sharing practices of homestay operators and local hotels in managing excess demand. During high guest numbers, excess visitors are transferred to other homestays or distributed to tour guides, indicating a concerned network that provides business opportunities for different stakeholders.

“Some people know how to serve the best Kandyan food, how to organize cultural activities.”

(Respondent 01: Personal Communication - 2026)

This finding also supports the existence of cooperative guest-sharing practice. Managers easily send redundant guests to others due to mutual trust and interdependence, enhancing cooperative relationships in the homestay sector.

4.1.2.3 Offering Package

“Hmmm..... In addition to accommodation, we provide Ayurvedic treatments and organic food to guests.”

(Respondent 03: Personal Communication - 2026)

This response focuses on the value-added diversification of homestay experiences in terms of organic produce and Ayurvedic therapies. In extending beyond mere provision of lodging, operators create unique experiences that target niche markets and enhance satisfaction.

“We partnered with a local tour operator to provide our clients with special packages that included transportation.”

(Respondent 06: Personal Communication - 2026)

This statement illustrates package collaboration through partnerships with indigenous tour operators. By putting together accommodation with cultural tours, performances, and indigenous experience, operators create holistic packages that enhance competitiveness and regional tourism.

4.1.2.4 Offer Divers Experience

“We arrange tours for tourists to Hanthana and Ambuluwa. For this, we are supported by the Amaya Hotel in Kandy.”

(Respondent 04: Personal Communication - 2026)

This is an example of collaborative tour organizing, whereby homestay operators collaborate with hotels such as the Amaya Hotel to organize excursions for tourists. Collaborations such as these serve to enrich tourist experience while encouraging cross-business cooperation.

“By staying at various homestays, we created a "Kandy Homestay Cycle" that enables visitors to see various areas of Kandy.”

(Respondent 05: Personal Communication - 2026)

By analyzing responses given by the interviewees it shows above by the main opportunities caused by homestay tourism operators when implementing an AS to enhance RR. In here respondent also men-

tioned sub-categories. They are Sharing resources, problem-solving, collaborative packages, joint packages, package deals.

Table 1. Category summary

Core Category	Category	Theme	Sub-Themes / Codes
Challenges	Challenges in working with other homestay operators	Communication barriers	1. Resistance to Change 2. Lack of Trust 3. Geographical Distance
		Competition	1. Differences in Service Standards
		Lack of coordination	
	Impact of limited funds and resources on teamwork	Limited investment	1. Limited Investment in Shared Marketing 2. Inability to Invest in Shared Initiatives 3. Fewer Resources 4. Reduced Participation
		Lack of Proper Training Opportunities	
		Low moral	
	Problems associated with collaboration and trust	Cultural and Social Differences	
		Lack of a Common Vision	1. Poor Management of Disagreements 2. Standards 3. Different Goals
		Mistrust	1. Mistrust with Past Experience
	Regulatory barriers to collaboration	Complicated Licensing and Regulations	1. Tight Building Regulations 2. Environmental Regulations
		Too many Rules	
		Tax Challenges	
Opportunities	Advantages of working with other homestay operators	Helping Each Other	1. Sharing Resources 2. Problem Solving
		Learning from each other	1. Knowledge Sharing
	Contribution of homestay grouping to visitor growth	Offering Package	1. Collaborative Packages 2. Joint Packages 3. Package Deals
		Destination appeal	1. Destination Promotion
		Offer diverse experience	—
	Benefits of sharing marketing and transportation resources	Joint marketing	1. Enhanced Marketing Impact 2. Joint Promotions at Travel Fairs 3. Wider Reach
		Shared transportation service	
	New opportunities and skills gained through collaboration	Networking	1. Partnering with Local Businesses 2. More Activities
		Reputation growth	
		Skill Development	1. Innovation

Source: Developed by researcher, 2026

4.2 *Objective 1 & 2 : To examine the Challenges and Opportunities faced by homestay tourism operators in implementing Agglomeration Strategy to strengthen Rural Resilience.*

The objective is to explore challenges and opportunities caused by homestay tourism operators when implementing AS to enhance RR. Based on the data gathered from the participants, the following subthemes were developed. According to the challenges and opportunities code, the core categories created sub-categories. Several studies have examined the potential and challenges associated with challenges and opportunities caused by homestay tourism operators when implementing AS to enhance RR. According to the challenge[14] investigated that the

main problems facing homestays are lacking physical facilities, as well as a lack of skilled workers, expertise, marketing plans, collaboration amongst tourism stakeholders, preservation of natural resources, and visitor safety. [15] explained in the research as challenges of Malaysia's homestay, they classified challenges into internal and external challenges; Lack of market understanding and awareness, insufficient networking, and a lack of innovation and entrepreneurship skills are a few of these. According to this study, Homestay-driven rural tourism in Nepal employs traditional homes to offer reasonably priced lodging, increasing local revenue and protecting the environment while improving the skills and standard of living of locals. This strategy promotes young involvement in community development, creates jobs, and reduces rural-to-urban migration. Another investigation carried out by [1] explored the opportunities in tourism makers or businesses promote rural economic development by creating jobs, reducing poverty, and giving disadvantaged groups, especially women. They provide visitors with genuine experiences that increase the attraction of the place while promoting intercultural dialogue, community pride, and personal development. The author found that although Kandy District homestay tourism operators deal with issues like financial limitations, competitiveness, mistrust, and communication challenges, they also gain from cooperation through destination branding, sharing of resources, and shared marketing. Considering laws and regulations, collaborative efforts in travel packages and creative experiences build RR, indicating that further collaboration and policy assistance may increase the sustainability of the homestay industry. Results appear to be consistent with these and other studies' findings, which suggest that enhancing communication, fostering trust between homestay operators, getting supportive regulations into place, and encouraging cooperative projects like resource sharing and joint marketing can all greatly increase the AS ability to strengthen RR.

5 CONCLUSION

This study demonstrates that homestay operator's perspectives integral to rural development that remain disproportionately vulnerable to economic and environmental shocks due to limited resources, weak institutional support, and dependence on external demand [4]. Content analysis was employed with 15 homestay operators in Kandy District validates this vulnerability while identifying concrete pathways through which resilience can be built.

The findings show in terms of challenges that collaboration among operators is constrained by interlocking relational, resource-based, and regulatory barriers[16]. Participants described communication difficulties, including resistance to change, mistrust among peers, and geographical distance, alongside competition arising from inconsistent service standards both of which weaken coordination at the grassroots level of the tourism eco-system [17][9]. These relational resistances are compounded by resource constraints such as limited investment capacity, inadequate training, and low morale were repeatedly cited as barriers to joint marketing or shared initiatives. Homestay operators also pointed to an absence of common vision and unresolved historical mistrust as deeper obstacles to sustained cooperation in rural context. Based on the internal dynamics, a regulatory environment marked by complex licensing procedures, restrictive building and environmental rules, and tax burdens was consistently reported as difficult for individual, small-scale operators to navigate solely when operate in businesses.

Simultaneously, the data point to substantial opportunities when agglomeration is pursued deliberately. Operators who engaged in mutual assistance and knowledge sharing reported improved capacity to solve operational problems collectively[18]. Diversified service packages were associated with stronger destination appeal while shared marketing and transportation arrangements, particularly joint participation in travel fairs, were linked to measurable gains in market reach and promotional visibility. Several operators reported improvements in networking, reputation, and skill development as a direct result of collaboration suggesting that agglomeration functions not only as a defensive response to vulnerability but as an active driver of competitiveness and growth[19].

These findings carry practical implications for policy and practice. Public policy should move beyond fragmented, ad-hoc

initiatives toward formal support for homestay clustering through cooperative governance frameworks. Empowering local tourism boards and cooperatives to coordinate shared marketing and standardized service protocols could reduce administrative burden on individual operators while strengthening collective competitiveness embracing the agglomeration concept. Targeted capacity-building programs in digital literacy, service diversification, and sustainable business practices further support long-term viability. Integrating homestay networks into broader regional tourism strategies may help bridge urban–rural divides and build resilience extending beyond individual enterprises. Embedding sustainability and community social responsibility into operational practice than treating it as secondary aid operators preserve local cultural heritage while withstanding volatile market conditions.

This study contributes to the limited empirical literature on how agglomeration strategies operate within developing-country tourism contexts offering context-specific insight from Sri Lanka. The findings should be interpreted in light of the study's limitations as the study utilized purposive based sample of 15 homestay operators drawn from a single district constrains statistical generalizability. Future research employing larger, multi-district samples or mixed-methods designs quantifying theme prevalence support in validate and extend these findings across the small tourism business in developing economies.

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Mobile Dependency in Higher Education: A Bibliometric Mapping of Nomophobia and Related Constructs Among University Students

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ABSTRACT: Mobile dependency is used as an umbrella term for constructs: nomophobia, smartphone addiction, mobile phone addiction, and problematic smartphone use. These constructs share a behavioral core of anxious, compulsive device engagement and are operationalized with overlapping instruments; the rationale for reviewing them jointly is set out in the Introduction. Research has grown over the past decade, yet it has developed in isolation from educational innovation, learning-technology scholarship, digital pedagogy, and educational design. This gap is notable because mobile devices are central to teaching, assessment, and student engagement in higher education. Understanding dependency patterns should inform curriculum and learning-platform design, individual-level intervention and institutional planning. This study presents a bibliometric review of 815 Scopus-indexed journal articles on mobile dependency among university students, published between 2019 and 2025 and screened under the PRISMA 2020 protocol. Performance analysis and science mapping, including keyword co-occurrence, thematic mapping, and conceptual structure analysis, traced publication trends, influential contributors, and the intellectual structure of the field. Annual output nearly quadrupled from 43 articles in 2019 to 165 in 2025. This growth coincided with the shift toward remote/hybrid education during COVID-19, although bibliometric evidence cannot establish causality. Thematic mapping shows that the field remains anchored in an individual-deficit tradition, with limited integration of learning design, educational technology, or digital pedagogy, a gap not addressed by prior bibliometric reviews. The review proposes a research agenda repositioning mobile dependency as an educational innovation challenge, with implications for curriculum design, learning management system governance, and institutional strategy for student digital wellbeing.

Keywords: Bibliometric analysis, educational innovation, higher education, mobile dependency, mobile learning, nomophobia

1 INTRODUCTION

Universities have become saturated with mobile technology, and institutions increasingly rely on smartphones and connected devices to deliver teaching, assessment, and student services. This digital dependence carries a psychological cost. Nomophobia, a term combining “no mobile phone” and “phobia,” describes the anxiety that arises when a person is separated from a mobile phone or unable to access it, and the construct was first linked clinically to panic and anxiety symptoms [1]. Researchers subsequently proposed that nomophobia be recognized as a distinct diagnostic entity [2] and developed validated instruments, most notably the Nomophobia Questionnaire, to measure its severity [3].

Among university students, nomophobia has been consistently associated with elevated anxiety, with prevalence estimates rising across successive cohorts [4], and it has been linked to depressive symptomatology in systematic reviews of problematic smartphone use [5], to measurable anxiety responses when device access is restricted [6], and to fear of missing out as a contributing mechanism [7]. These findings sit within a broader framework that treats problematic smartphone use as a form of behavioral addiction [8], and this framing has shaped how the construct has been studied ever since.

Nomophobia, smartphone addiction, mobile phone addiction, and problematic smartphone use are treated jointly in this review because they are overlapping operationalization of a single underlying phenomenon rather than four independent literatures. Nomophobia refers specifically to the anxiety triggered by separation from, or inability to use, a mobile phone [1], [3], whereas smartphone addiction and problematic smartphone use describe the broader compulsive-use pattern from which that anxiety arises [5], [8]; mobile phone addiction is used largely interchangeably with smartphone addiction in earlier records that predate the smartphone's market dominance. Because validated nomophobia instruments share item content with smartphone-addiction scales, and because Scopus indexing frequently assigns overlapping author keywords across the four terms, treating them as a single combined dataset avoids artificially fragmenting a literature that already treats them as points on one construct; a pooling approach also adopted in prior bibliometric mappings of this literature [20].

University students are relevant to educational innovation scholars for two further reasons that this clinical framing does not capture. First, the academic environment now functions as a managed digital ecosystem in which learning management systems, mobile applications, and constant messaging shape engagement and performance, so nomophobia is as much an institutional design question as a clinical one. Second, the device dependence patterns associated with anxiety and reduced performance in university settings intersect directly with how courses are designed and delivered, since blended and mobile-enabled learning environments are themselves built on the very devices implicated in the construct [9]. How nomophobia research has developed is therefore relevant not only to student mental health but to how universities design curricula, learning platforms, and teaching practices for a generation whose relationship with technology differs from that of previous cohorts.

Despite this practical relevance, the nomophobia literature has developed almost entirely within psychiatry, clinical psychology, and public health. Educational innovation and learning-design perspectives, including technology acceptance [18], mobile-learning theory [16], and learning analytics [19] frameworks that are well established in research on classroom technology use, are rarely brought into conversation with this literature.

Two recent bibliometric mappings intersect with the present review. Wong, Yeo, and Lee [20] analyzed 924 Scopus-indexed smartphone-addiction publications and identified risk-factor, prevalence, and intervention themes through co-word analysis, and Bhattacharya, Singh, and Singh [21], in a 2010–2024 bibliometric mapping of nomophobia, similarly reported a field concentrated in medicine and psychology with limited disciplinary spread. Neither review examined the field's engagement, or lack of it, with educational innovation, mobile learning, or learning-design scholarship, nor did either restrict its sample to a university-student population in order to draw institutional implications for higher education specifically. The present review builds on this prior bibliometric work but is distinguished by its explicit focus on the university-student sub-literature and by its use of thematic mapping to assess cross-disciplinary integration with educational innovation research, rather than only describing the field's internal productivity and thematic structure.

This study addresses that gap through a bibliometric review guided by three research questions. RQ1 asks how scientific production and citation impact in this field have evolved over time. RQ2 asks which authors, sources, and countries have shaped the field, and what this concentration reveals about its disciplinary orientation. RQ3 asks what the thematic and conceptual structure of the literature reveals about the balance between clinical and educational-innovation-relevant perspectives, and where the two might be productively integrated. In answering these

questions, the review contributes a research agenda that connects mobile dependency to higher education policy and to educational innovation research on technology-enabled learning.

2 METHODOLOGY

This review follows a bibliometric review design, applying the PRISMA 2020 protocol [11] for identification, screening, and inclusion, and complementing it with science mapping techniques for thematic analysis. Records were retrieved from the Scopus database on 10 May 2026 using the following Boolean string applied to the title, abstract, and keyword fields: TITLE-ABS-KEY (nomophobia OR "no mobile phone phobia" OR "smartphone addiction" OR "smart phone addiction" OR "mobile phone addiction" OR "problematic smartphone use" OR "problematic mobile phone use") AND TITLE-ABS-KEY (student* OR undergraduate* OR postgraduate* OR university OR college OR "higher education") AND PUBYEAR > 2018 AND PUBYEAR < 2026 AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English")). Searches were limited to peer-reviewed journal articles published in English between 2019 and 2025 inclusive.

Following the PRISMA 2020 flow, 1,238 records were identified through the Scopus search; 14 duplicate records were removed, leaving 1,224 records for title-and-abstract screening. Titles and abstracts were screened against a single relevance criterion requiring that the study examine nomophobia or a closely related construct within a university student population; 306 records were excluded at this stage for addressing device use in unrelated populations or contexts, for not being original research, or for insufficient thematic relevance. The remaining 918 full-text articles were assessed for eligibility, and 103 were excluded (40 for studying a non-university-student population, 41 for not being peer-reviewed journal articles, and 22 for being published in a language other than English), yielding the final analytic sample of 815 documents (Fig. 1 summarizes annual output over the review period). Screening was conducted independently by two of the authors, with disagreements resolved through discussion with the third author until consensus was reached. As with any bibliometric review, this process depends on a single database and an English-language restriction, and the implications of these choices for the representativeness of the findings are addressed in the concluding section.

Prior to keyword and thematic analysis, near-synonymous keyword variants (e.g., "smart phone addiction" and "smartphone addiction"; "college student" and "university student") were merged using bibliometrix's synonym-merging function. Keywords occurring in fewer than three documents were excluded from network and thematic mapping to reduce noise, and thematic maps were built on author keywords using the centrality-density algorithm [14] with the Walk trap clustering algorithm and a minimum cluster size of five documents.

Bibliometric performance indicators, including annual scientific production, citation metrics, author and source productivity, and Lotka's law of author productivity [15], were computed alongside science mapping techniques such as keyword co-occurrence analysis, thematic mapping based on the centrality-density framework [14], multiple correspondence analysis, and hierarchical clustering. All analyses were conducted using the bibliometrix R package accessed through its Biblioshiny interface [13], following established guidelines for bibliometric analysis [12]. Thematic mapping classifies keyword clusters into four quadrants defined by centrality, or relevance to the field, and density, or internal development, labelled motor, basic, niche, and emerging or declining themes. This classification is used here not only to describe the field's structure but to assess how far educational innovation and learning-design constructs have been integrated into what the results show to be a predominantly clinical literature.

3 RESULTS

3.1 *Performance Analysis*

Annual scientific production on mobile dependency among university students rose from 43 documents in 2019 to 165 in 2025, an increase of almost fourfold (Fig. 1). Growth was gradual before 2021 and accelerated sharply afterward, a pattern that temporally coincides with the widespread adoption of remote and hybrid learning during

and after the COVID-19 pandemic; this association is descriptive rather than causal, since a bibliometric count cannot establish that the pandemic drove the increase in publications. Average citations per year peaked around 2020 at approximately 6.2 citations and declined to approximately 1.2 by 2025. This decline reflects the normal citation accumulation lag of recent publications rather than any loss of relevance, and it should be read alongside the production data as evidence of a field still in an expansion phase.

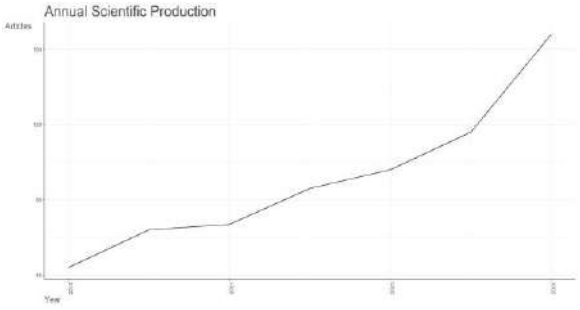


Figure 1. Annual scientific production of mobile dependency research among university students, 2019–2025

Author productivity followed Lotka's law of scientific productivity: most contributing authors published a single document, while a small group of scholars produced a disproportionate share of the literature, a pattern typical of a young, consolidating field. M.D. Griffiths was the most productive author, with sixteen documents and the highest local h-index of ten, followed by Lin C.Y., Wang Y., and Zhang G. with eleven documents each, and Elhai J.D. with nine documents and a local h-index of nine (Table 1). Griffiths' prominence is notable because his work established the components model of addiction that frames much of the field's conceptual vocabulary [8], a framework developed within clinical psychology rather than educational innovation or learning-design research. Frontiers in Psychology and Addictive Behaviors were together the two most prolific and highest-impact outlets, both recording a local h-index of sixteen, followed by the Journal of Affective Disorders and the Journal of Behavioral Addictions with a local h-index of twelve each. This concentration in psychology and psychiatry journals is consistent with the field having developed largely outside educational innovation scholarship, even though its subject matter the behavioral and instructional consequences of constant connectivity is directly relevant to that literature. The most cited document in the dataset, by Elhai and colleagues (2020, Addictive Behaviors), accumulated 249 citations, followed by Leung et al. (2020, Addictive Behaviors, 234 citations) and Geng et al. (2021, Journal of Affective Disorders, 227 citations) (Table 1). China was the leading contributing country by publication volume, consistent with the concentration of highly cited authors and sources in East Asian institutions.

Table 1. Leading authors, sources, and most-cited documents

Category	Entity	Metric
Most productive author	Griffiths M.D.	16 docs (h = 10)
	Lin C.Y., Wang Y., Zhang G.	11 docs each
	Elhai J.D.	9 docs (h = 9)
Most prolific source	Frontiers in Psychology	50 docs (h = 16)
	Addictive Behaviors	30 docs (h = 16)
Most cited document	Elhai et al., 2020, Addict. Behav.	249 citations
	Leung et al., 2020, Addict. Behav.	234 citations
	Geng et al., 2021, J. Affect. Disord.	227 citations

Source: Bibliometric analysis output (Biblioshiny).

3.2 *Science Mapping*

The most frequent keywords smartphone addiction (89 occurrences), nomophobia (63), problematic smartphone use (54), university students (52), mobile phone addiction (49), and anxiety (47) point to a vocabulary built around addiction and clinical symptomatology rather than around use, adoption, or performance, the terms that would be expected if educational innovation and learning-design research had shaped the field to a similar degree. Hierarchical clustering of keywords reinforces this reading. Two broad clusters emerge: one grouping psychological and behavioral correlates such as anxiety, depression, loneliness, sleep quality, self-control, and psychological distress, and a second grouping device-specific and demographic terms such as smartphone addiction, nomophobia, gender, academic performance, and mental health. Neither cluster contains vocabulary associated with established educational-technology frameworks, such as mobile-learning theory [16], student technology-engagement research

[17], technology acceptance models [18], or learning analytics [19], suggesting at the level of keyword co-occurrence that these literatures have developed largely independently of one another.

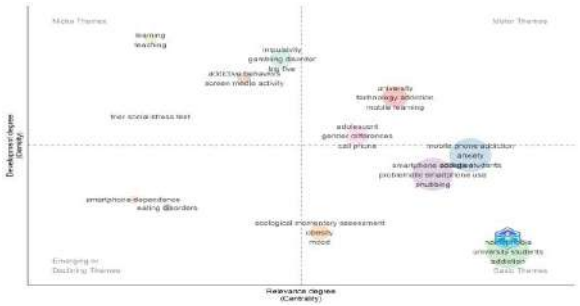


Figure 2. Thematic (strategic) map of mobile dependency research: centrality versus density

Thematic mapping (Fig. 2) positions smartphone addiction, mobile phone addiction, anxiety, problematic smartphone use, phubbing, and technology addiction as motor themes, meaning they are both central to the field and internally well developed. Nomophobia, university students, adolescent, gender differences, and cell phone form the basic themes that underlie the field without being theoretically well developed themselves. Learning and teaching, impulsivity, gambling disorder, and the Big Five personality traits occupy the niche quadrant, representing a smaller, specialized stream connecting nomophobia to individual differences research. Smartphone dependence, eating disorders, ecological momentary assessment, obesity, and mood sit in the emerging or declining quadrant.

These four quadrants do not represent a simple progression from foundational to advanced knowledge. They instead reflect at least two parallel and only loosely connected traditions. The first, comprising the motor and basic themes, treats nomophobia as a clinical symptom cluster to be measured, diagnosed, and predicted from personality and demographic variables. The second, visible mainly in the niche quadrant, treats nomophobia as one manifestation of a broader vulnerability to behavioral addiction, connecting it to gambling and impulsivity research. A third, still emerging perspective, visible in the ecological momentary assessment and latent profile analysis terms appearing in the most recent trend data (Fig. 3), treats nomophobia as a dynamic, situational state that fluctuates within a person over time rather than as a fixed trait. None of the three traditions engages directly with educational innovation constructs such as technology acceptance, instructional design, or institutional readiness for mobile-enabled learning, which is the central gap this review identifies.

3.3 *Trend Topics*

Trend topic analysis (Fig. 3) traces this evolution in more detail. Early general terms such as mobile phone, internet, and smartphone usage were prominent around 2020, giving way to population-specific inquiry, including medical students and higher education, in 2021. The core constructs of nomophobia, smartphone addiction, and problematic smartphone use consolidated in 2023, and their clinical correlates anxiety, mobile phone addiction, and university students became prominent in 2024. The most recent terms, physical exercise, network analysis, and latent profile analysis in 2025, point toward intervention-based and person-centered analytic approaches as a plausible next direction for the field, though even these remain framed in clinical rather than educational terms.

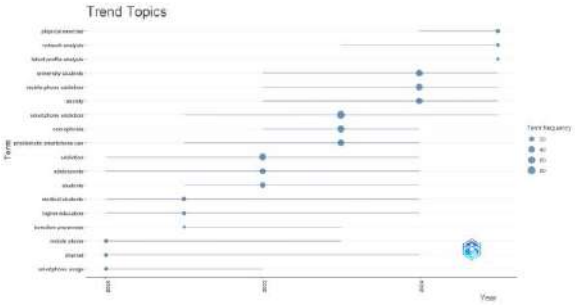


Figure 3. Trend topics in mobile dependency research among university students, 2020–2025

4 DISCUSSION

The results show a field that has matured steadily in volume and citation impact but has done so almost entirely within a clinical paradigm, a pattern already visible in the concentration of the most productive authors and journals in psychology and psychiatry rather than in education, learning technology, or educational innovation outlets. This is broadly consistent with the disciplinary concentration reported by Wong et al. [20] for smartphone addiction and by Bhattacharya

et al. [21] for nomophobia specifically, though neither prior review examined the university-student sub-literature's engagement with educational innovation scholarship, which is the focus adopted here. This pattern has two implications for educational innovation scholarship. First, universities function as learning organizations, and nomophobia's well-established association with anxiety and reduced academic performance is directly relevant to how institutions design digital learning environments, plan student support services, and design policies for the responsible use of mobile technology in teaching. The absence of educational innovation theory in this literature suggests that these institutional questions have, to date, been addressed mainly through health-service and clinical channels rather than integrated into higher education and educational innovation research; this interpretation follows from the absence of relevant keywords and outlets in the mapping and should be treated as a plausible reading of the evidence rather than a demonstrated causal account.

Second, the same behavioral pattern that produces nomophobia in university students near-constant device checking and anxiety when disconnected has direct conceptual parallels in the literature on learning environments and instructional design. The demands-resources logic developed to explain strain in high-demand settings [9] could plausibly apply to academic contexts, where constant connectivity may function as a demand that depletes the attentional and cognitive resources students need for sustained learning, while technology acceptance research [18] offers one possible explanation for why students continue to rely on a technology despite negative consequences. Neither framework has been tested against nomophobia data in the literature identified in this review, so both are presented here as untested, plausible extensions rather than established explanations, and they represent a currently unrealized opportunity for educational innovation research.

Table 2 summarizes these observations as a proposed, currently untested research agenda organized around the field's thematic maturity. For the well-established motor and basic themes, the priority is theoretical integration: testing whether technology acceptance and demands-resources constructs explain variance in nomophobia beyond existing clinical predictors, and whether nomophobia observed during university is associated with measurable learning outcomes such as attention, retention, and academic performance. For the niche, individual-differences stream, the priority is to test whether the addiction-vulnerability profile associated with gambling and impulsivity generalizes to classroom and study-related technology behaviors. For the emerging quadrant, ecological momentary assessment and latent profile analysis offer tools that learning-analytics researchers already use to study engagement over time [19] and could equally be applied to track how mobile dependency develops across a student's academic journey.

Table 2. Comparative thematic summary and proposed educational-innovation research agenda (untested directions)

Quadrant	Representative themes	Underlying tradition	Proposed future direction
Motor (established)	Smartphone/mobile phone addiction, anxiety, phubbing	Clinical/addiction paradigm	Test whether technology acceptance and learning-engagement constructs explain variance beyond existing clinical predictors
Basic (foundational)	Nomophobia, university students, gender, adolescent	Descriptive/diagnostic paradigm	Track, via longitudinal designs, whether nomophobia predicts learning engagement and academic performance
Niche (specialized)	Impulsivity, gambling disorder, Big Five	Individual-differences paradigm	Test whether addiction-vulnerability profiles generalize to classroom and study-related technology behaviors
Emerging/declining	Ecological momentary assessment, latent profile analysis, physical exercise	Person-centered, intervention paradigm	Apply EMA and latent-profile methods from learning-analytics research to track dependency across a student's academic journey

Source: Authors' synthesis of thematic mapping results.

5 IMPLICATIONS FOR EDUCATIONAL INNOVATION

The following implications are offered as potential considerations for institutions to weigh, not as validated interventions; none has been empirically tested in the present bibliometric study.

5.1 *Theoretical implications*

The mapping suggests technology acceptance [18] and demands-resources theory as candidate frameworks for explaining nomophobia in academic settings, and positions learning analytics [19] as a methodological bridge between clinical and educational-innovation research on device dependency. These are theoretical propositions arising from the bibliometric gap identified, and require empirical testing.

5.2 *Educational practice implications*

Faculty development programs could, in principle, equip instructors to design mobile-enabled learning activities that channel smartphone use toward engagement rather than distraction; whether this reduces dependency-related harm has not been tested here and would require intervention studies.

5.3 *Policy implications*

Curriculum and learning-technology policy could be evaluated not only for pedagogical effectiveness but for its potential contribution to problematic device dependence, an evaluation that educational innovation research is well placed to conduct in partnership with student-wellbeing units.

5.4 *Technology design implications*

Learning management system governance could consider structured attention breaks,

notification management, and mobile-use guidelines as part of course design, as one option among several rather than as leaving device use entirely to student self-regulation.

5.5 *Future research implications*

Beyond the agenda in Table 2, complementary co-citation, bibliographic coupling, and collaboration-network analyses would deepen understanding of the field's intellectual and social structure and are recommended as a direct extension of this review.

6 LIMITATIONS AND CONCLUSION

This review is limited by its reliance on a single database, Scopus, by its restriction to English-language publications, and by the macro-level nature of bibliometric analysis, which cannot capture study-level effect sizes or methodological quality. Complementary meta-analytic and qualitative syntheses, and empirical studies that directly test the educational innovation theories proposed here, are needed to build on these findings. The claims in this review that are supported directly by the bibliometric data as publication growth, author and source concentration, and keyword/thematic structure should be distinguished from the technology-acceptance and demands-resources connections proposed in the Discussion, which are interpretive propositions for future testing rather than findings of this study.

In conclusion, mobile dependency among university students is a rapidly expanding field of research that remains anchored in clinical and addiction-based paradigms, with little engagement from educational innovation and learning-design scholarship despite an evident practical relevance to how higher education institutions design curricula, learning platforms, and teaching practices. Connecting this literature to technology acceptance and demands-resources research offers one concrete route toward that engagement, and toward institutional responses that treat mobile dependency as a phenomenon that universities are well positioned to help address through deliberate learning design.

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Factors Influencing Sustainable Fashion Avoidance among Millennial Consumers in Sri Lanka: A Brand Avoidance Perspective

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ABSTRACT: Sustainable fashion is presented as a response to the environmental and social costs of conventional apparel, yet consumers may still avoid it. This study examines associations between four proposed factors and sustainable fashion avoidance intention in a cross-sectional online survey of Sri Lankan millennials. The survey contained 303 responses; 302 recorded explicit consent and were included. Four item scores for functional avoidance, symbolic avoidance, moral avoidance and perceived knowledge deficit were entered in an ordinary least squares regression. The model was statistically significant, $F(4, 297) = 6.661$, $p < 0.001$, but explained 8.2% of the variation in avoidance intention. Only symbolic score had a significant adjusted association, and it was inverse ($\beta = -0.272$, $p < 0.001$). Functional ($\beta = -0.067$, $p = 0.365$), moral ($\beta = 0.043$, $p = 0.453$) and knowledge deficit ($\beta = 0.068$, $p = 0.283$) scores were not significant in the joint model. Functional scale reliability was below 0.70 ($\alpha = 0.660$). The inverse symbolic finding, provisional measures and concentrated convenience sample limit interpretation. The study identifies a relationship requiring further investigation, rather than causal drivers of purchases.

Keywords: sustainable fashion; brand avoidance; Sri Lanka; millennials; symbolic identity; consumer intention

1 INTRODUCTION

1.1 *Background and problem*

Fashion production and consumption impose substantial environmental pressures, while sustainable fashion encompasses different approaches to reducing harm across products and supply chains [1], [2]. Yet favourable views of sustainability do not consistently translate into clothing purchases [3]. Understanding avoidance intention may therefore clarify how consumers evaluate the practical and personal fit of sustainable apparel. This study tests four proposed associations among Sri Lankan adults aged 25 to 40, using the original online survey rather than treating a positive environmental attitude as evidence of purchasing behaviour.

1.2 *Research gap and objective*

Earlier brand avoidance research distinguishes rejection arising from unmet expectations, identity conflict and moral objections [4]. A recent study applied a modified avoidance model to sustainable fashion shoppers in South Africa [5]. The present analysis considers functional, symbolic and moral scores together with perceived knowledge deficit in a Sri Lankan sample. It asks which variables remain associated with avoidance intention when the others are held constant. Because respondents were recruited by convenience and the questionnaire measured intention rather than observed purchases, the findings concern this sample

and cannot establish causes or population prevalence.

The research question is: How are functional, symbolic and moral avoidance scores and perceived knowledge deficit associated with sustainable fashion avoidance intention in the sampled Sri Lankan adults? The objective is to estimate the direction and strength of each association in a joint model. Studying intention is useful, but it must not be equated with actual refusal to buy sustainable clothing.

2 LITERATURE REVIEW AND HYPOTHESES

2.1 *Brand avoidance and functional concerns*

Lee and colleagues distinguish experiential, identity and moral forms of brand avoidance [4]. In this study, functional concerns are approximated by items on perceived quality, durability, expectations and value; symbolic concerns by items on style, social image and identity; moral concerns by avoidance of unethical brands and preference for social responsibility. Knowledge deficit adds uncertainty about sustainable fashion concepts and claims. These are adapted survey domains, not proven dimensions of a single validated avoidance scale. Research on eco-clothing relates purchase decisions to identity and the social meaning of appearance [6]. Working on fast fashion also describes the tension between style desires and sustainability [7]. Studies of eco-conscious apparel acquisition identify practical and informational barriers [8].

Functional avoidance in the brand avoidance literature concerns disappointed expectations and unsatisfactory product performance [4]. In this questionnaire, three items directly mention poor quality, unmet expectations and durability. A fourth refers generally to avoiding brands without value for money. That broader wording may reflect price or perceived worth rather than a product failure specific to sustainable fashion. Therefore, the four item average is an approximate indicator of functional concerns, not a verified measure of functional avoidance. Sustainable apparel research has identified practical barriers such as difficulty locating suitable products and doubts about value [8].

2.2 *Identity and competing explanations*

An alternative account is the theory of planned behavior, which emphasizes attitudes, social norms and perceived control as determinants of intention [9]. Its attention to perceived control makes affordability and access plausible influences, while identity research draws attention to social image in clothing choice [3], [6]. Recent work on high volume fashion consumers shows that stated sustainability concern can coexist with high garment consumption [10]. This design did not measure the full planned behavior model, actual purchases or attitudes to specific brands, so it cannot adjudicate between theories or demonstrate an attitude–behavior gap in this sample.

Symbolic avoidance refers to a perceived mismatch between a brand and a consumer's self-concept [4]. Clothing can communicate personal style and social identity [6]. The current items ask whether sustainable fashion fits personal style and social image, whether consumers reject brands that do not match identity, and whether they prefer brands that improve self-image. The last item describes a general preference and could have a different interpretation from rejection of sustainable fashion. This matters when interpreting the negative coefficient. Moral avoidance is also conceptually distinct: disagreement with a brand's conduct can lead to rejection, but the present moral items often express support for ethical behavior rather than rejection of sustainable products. Greenwashing literature provides a reason to study credibility, but no brand's actual conduct was measured here [11], [12].

2.3 *Consumer knowledge deficit*

Knowledge deserves separate attention because knowledge of sustainability differs from confidence in a brand's claims. Han and colleagues report an association between accurate sustainability knowledge and purchase intention in other Asian samples [13]. The present questionnaire instead asks about information shortage, conceptual difficulty, brand authenticity and limited awareness. Its score therefore combines related but distinct perceptions; a null coefficient here cannot overturn findings based on objective knowledge tests.

2.4 *Hypotheses and conceptual framework*

H1 proposes an association between functional score and sustainable fashion avoidance intention. H2 proposes an association between symbolic score and avoidance intention.

H3 proposes an association between moral score and avoidance intention. H4 proposes an association between perceived knowledge deficit score and avoidance intention. These hypotheses are non-directional because adapted items mix statements about rejection, brand preference and ethical approval. All four scores enter the same model; the framework tests adjusted statistical associations, not causal pathways.

3 METHODOLOGY

3.1 *Design and respondents*

The study used a cross-sectional online questionnaire circulated through Facebook, Instagram, WhatsApp and LinkedIn. Convenience sampling did not give every eligible person a known chance of selection. Survey timestamps place the recorded responses on 8–9 April 2026. Of 303 records, 302 selected "Yes" to voluntary participation; one "Yes;No" response was ambiguous and excluded before analysis. The analysed respondents selected age bands 25–30, 31–35 or 36–40.

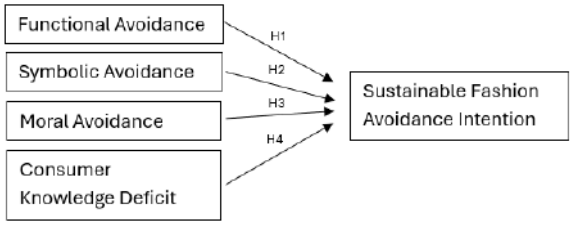


Figure 1. Conceptual framework

These bands overlap the millennial cohort but cannot establish each person's birth year, and the youngest respondents may fall outside commonly used millennial boundaries. The findings therefore apply to the sampled age bands rather than all Sri Lankan millennials. The study plan proposed employment, income and awareness screening, but recorded students and unemployed participants show that those conditions cannot be treated as enforced. The number invited, response rate and independent eligibility checks were not recorded.

3.2 *Questionnaire and operational definitions*

The questionnaire contained demographic questions and 20 agreement statements, grouped into five proposed four item scales. Response options were coded 1 for strongly disagree through 5 for strongly agree. Functional items concerned quality, expectations, durability and value. Symbolic items concerned style, social image, identity and self-image. Moral items concerned ethical practice, environmental harm and social responsibility. Knowledge items concerned insufficient information, difficulty understanding sustainable fashion, uncertain authenticity and limited awareness. The outcome items asked about deliberately avoiding sustainable fashion, preferring alternatives, lacking interest and being unlikely to purchase it. Each scale score was the arithmetic mean of its four recorded items; higher outcome values indicate more stated avoidance. Because some predictor items are affirmative preferences or general brand statements, no reverse coding was imposed without evidence that such a transformation matched the questionnaire's intended meaning. No included record lacked a scale response after normalizing category capitalization. These operational choices allow replication but leave construct meaning and item direction open to further validation.

3.3 *Statistical analysis*

Cronbach's alpha was calculated for internal consistency. Pearson's correlation coefficient summarized the unadjusted relationship between each predictor and the outcome. The joint ordinary least squares model regressed the four-item avoidance intention mean on the four predictor means. Unstandardized coefficients (B), standardized coefficients (β), t statistics, two-sided p values, a 95% confidence interval for the significant symbolic coefficient, R^2, adjusted R^2, F and variance inflation factors (VIF) are reported below. The significance threshold was 0.05. The model's standard errors use conventional ordinary least squares assumptions; no claim of fully verified residual normality or constant variance is made. Cross sectional, self-reported and nonran-

dom data permit association estimates but cannot establish causal effects or population prevalence.

3.4 *Ethics*

A voluntary participation question was included and analysis retained only explicit "Yes" responses. The study records available for this article do not document an institutional ethics approval or exemption, the information presented before consent, anonymization procedures, or a retention policy. These details need to be verified, and the appropriate approval or exemption statement supplied before submission. A positive answer to a participation question is evidence of an expressed response, not of institutional review.

4 RESULTS

4.1 *Respondent profile*

Table 1 summarises the 302 explicitly consenting respondents. The sample was concentrated among women (79.8%) and respondents aged 31–35 (87.4%); 83.8% held a degree or diploma. These distributions describe the online convenience sample and should not be interpreted as representative of Sri Lankan millennials.

Table 1. Respondent profile in the analysed sample (N = 302)

Group	Category	n (%)
Age	25–30	21 (7.0)
	31–35	264 (87.4)
	36–40	17 (5.6)
Gender	Female	241 (79.8)
	Male	61 (20.2)
Education	Degree	145 (48.0)
	Diploma	108 (35.8)
	Postgraduate	33 (10.9)
	School level	16 (5.3)
Employment	Full time employed	102 (33.8)
	Self employed	102 (33.8)
	Part time employed	72 (23.8)
	Student	15 (5.0)
	Unemployed	11 (3.6)
Monthly income	Below LKR 50,000	27 (8.9)
	LKR 50,000–100,000	138 (45.7)
	LKR 100,000–150,000	113 (37.4)
	Above LKR 150,000	24 (7.9)

4.2 *Descriptive Statistics*

Descriptive statistics summarised the study variables, while Pearson correlations examined their unadjusted relationships with sustainable fashion avoidance. Symbolic avoidance recorded the highest mean (M = 3.5924, SD = 0.66091), whereas sustainable fashion avoidance recorded the lowest (M = 2.8003, SD = 0.86108).

Functional and symbolic avoidance were negatively correlated with sustainable fashion avoidance ($r = -0.201$ and -0.275, respectively; $p < .001$). Moral avoidance ($r = -0.074$, $p = .200$) and consumer knowledge deficit ($r = -0.078$, $p = .174$) were not significantly correlated with the outcome. These bivariate relationships were examined further in the joint regression model.

4.3 *Reliability Analysis*

The internal consistency of the five study constructs was assessed using Cronbach's alpha. Each construct was measured using four questionnaire items, and the analysis included 303 responses. As shown in Table 1, sustainable fashion avoidance intention had the highest reliability ($\alpha = .871$). Symbolic avoidance ($\alpha = .795$), consumer knowledge deficit ($\alpha = .760$), and moral avoidance ($\alpha = .744$) also exceeded the .70 criterion. Functional avoidance produced an alpha of .668, which was slightly below this criterion. Therefore, four of the five scales met the selected reliability criterion. Findings involving functional avoidance should be interpreted with caution because its items showed weaker internal consistency.

Table 2. Descriptive statistics and correlations with sustainable fashion avoidance

Construct	Mean	SD	r	p
Functional avoidance	3.4150	0.52385	-0.201	<.001
Symbolic avoidance	3.5924	0.66091	-0.275	<.001
Moral avoidance	3.4172	0.54875	-0.074	.200
Consumer knowledge deficit	3.5253	0.62721	-0.078	.174
Sustainable fashion avoidance	2.8003	0.86108	-	-

Table 3. Reliability analysis of the study measures

Construct	Number of items	Cronbach's alpha	Interpretation
Functional avoidance	4	.668	Below .70 criterion
Symbolic avoidance	4	.795	Reliable
Moral avoidance	4	.744	Reliable
Consumer knowledge deficit	4	.760	Reliable
Sustainable fashion avoidance intention	4	.871	Highly reliable

4.4 *Regression Analysis and Hypothesis Testing*

The joint ordinary least squares regression was statistically significant, $F(4, 297) = 6.661$, $p < .001$, but explained 8.2% of the variation in sustainable fashion avoidance intention ($R^2 = .082$). Only symbolic score remained a statistically significant independent predictor after adjustment ($\beta = -.272$, $p < .001$). Functional ($\beta = -.067$, $p = .365$), moral ($\beta = .043$, $p = .453$), and knowledge deficit ($\beta = .068$, $p = .283$) scores were not significant in the joint model.

The inverse symbolic coefficient indicates that higher symbolic scores were associated with lower reported avoidance after controlling for the other predictors. H2 was therefore supported as a statistical association, although the direction complicates substantive interpretation. H1, H3 and H4 were not supported in the adjusted model. Given the convenience sample, cross-sectional design and adapted measures, these results should be interpreted as associations rather than causal effects.

5 DISCUSSION

5.1 *Symbolic score and identity*

Symbolic score was the only independent predictor meeting the statistical threshold in the joint model, but its inverse sign complicates theoretical interpretation. A South African study using a modified brand avoidance model identified symbolic incongruence as relevant to sustainable fashion avoidance [5], while other research links clothing choice with social identity and self-expression [3], [6]. In this sample, however, higher symbolic scores corresponded to lower reported avoidance after adjustment. Mixed item direction may partly explain this result: a general preference for brands that enhance self-image does not necessarily measure rejection of sustainable fashion. The concentrated sample may also differ from populations examined elsewhere. Neither explanation was tested directly, so the finding requires replication using clearly worded, consistently directed items before stronger theoretical conclusions are drawn.

Table 4. Joint regression and hypothesis testing

Predictor	β	p	Result
Functional avoidance	−.067	.365	Not supported
Symbolic avoidance	−.272	<0.001	Supported
Moral avoidance	.043	.453	Not supported
Consumer knowledge deficit	.068	.283	Not supported

Fashion remains an important form of self-expression, meaning that sustainability attributes are likely to be evaluated alongside design, lifestyle compatibility and desired social image. For practitioners, this cautions against assuming that environmental positioning alone will create preference. Sustainable offerings may still need to compete on aesthetics and identity relevance. At the same time, the negative adjusted coefficient means the present data do not justify a claim that symbolic mismatch causes avoidance; the result is better treated as a measurement-sensitive association requiring confirmation.

5.2 *Functional, moral and knowledge scores*

Functional score was inversely correlated with avoidance intention at the bivariate level but was nonsignificant after adjustment. Its below-benchmark reliability and broad value-for-money item further limit interpretation. Moral score and perceived knowledge deficit were also nonsignificant in the joint model. These findings should not be read as evidence that ethics or information are unimportant. The moral items mainly captured support for ethical practice, which does not necessarily imply rejection of sustainable products, while the knowledge measure assessed perceived information gaps rather than objective knowledge. This differs from research connecting objectively assessed sustainable-

fashion knowledge with purchase intention [13]. Similarly, greenwashing research highlights the importance of claim credibility [11], [12], but the present survey did not measure actual misleading claims or responses to named brands. The distinction between bivariate and adjusted findings is important. A variable may show an association with avoidance when examined alone but contribute little unique explanatory power once overlapping predictors are considered simultaneously. Functional considerations such as quality, durability, accessibility and perceived value may still matter in real purchasing contexts, but this dataset does not establish an independent adjusted effect. Likewise, the nonsignificant moral and knowledge coefficients should be interpreted as sample-specific statistical results rather than evidence that ethical concerns or sustainability education have no role in consumer decision making.

5.3 *Managerial implications and future research*

For managers, the findings are best used to frame exploratory questions rather than prescribe proven interventions. Interviews could investigate whether consumers perceive sustainable clothing as compatible with personal style, how they evaluate durability and value, and what evidence makes sustainability claims credible. This may help brands identify whether avoidance reflects product performance, identity fit, information uncertainty, or other barriers not captured adequately by the current measures.

Further research should revise the questionnaire to distinguish rejection of sustainable products from rejection of unethical conventional brands, verify the factor structure, and specify which items require reverse coding. Research using a broader age and gender distribution, measured purchasing behaviour and a sampling strategy with known coverage would help determine whether the inverse symbolic association recurs. Experimental work could then test whether specific design, pricing or communication changes alter consumer choices. The present cross-sectional regression cannot establish that any such intervention would increase sustainable-fashion purchases.

The modest explanatory power of the joint model also indicates that substantial variation in avoidance intention remains outside the four proposed scores. Future studies could therefore examine additional influences such as price sensitivity, product availability, perceived quality, fashion involvement, peer influence, trust in sustainability claims and prior purchasing experience. Separating stated intention from observed purchasing would be particularly valuable because consumers may express support for sustainability without making corresponding clothing choices. Longitudinal or experimental designs would also provide stronger evidence about whether changes in product attributes or communication precede changes in behaviour. Until such evidence is available, managerial recommendations should remain exploratory and should not be presented as proven causal solutions.

6 CONCLUSION

6.1 *Summary and limitations*

This study examined four proposed correlates of sustainable fashion avoidance intention among 302 explicitly consenting Sri Lankan adults aged 25–40. The joint model was significant but explained only 8.2% of variation in intention. Symbolic score was inversely associated with intention ($\beta = -.272$, $p < .001$), while functional, moral and perceived knowledge deficit scores were nonsignificant after adjustment. The concentrated convenience sample, mixed item wording, weaker functional-scale reliability, unverified factor structure, self-reported intention and cross-sectional design limit interpretation. The study therefore identifies an association requiring further investigation rather than causal drivers of sustainable fashion purchasing.

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Explainability of AI Credit Decisions and BNPL Continuance: The Moderating Role of Financial Literacy

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ABSTRACT: Artificial Intelligence (AI) is increasingly used in Buy Now, Pay Later (BNPL) services to support automated credit decisions. This study examines the association between perceived explainability of AI credit decisions and consumers' continuance intention to use BNPL services and assesses the moderating role of financial literacy in Sri Lanka. A quantitative cross-sectional survey of 404 BNPL users was analysed using IBM SPSS Statistics and Hayes' PROCESS Macro. Perceived explainability was positively and significantly associated with continuance intention. Financial literacy showed a positive direct association with continuance intention, but its interaction with perceived explainability was not statistically significant. Thus, financial literacy did not moderate the focal relationship. The findings extend explainable-AI research to post-adoption BNPL use and highlight the relevance of understandable AI-supported credit decisions.

Keywords: Explainable AI, BNPL, perceived explainability, continuance intention, financial literacy

1 INTRODUCTION

Artificial Intelligence (AI) has found its way into various aspects of financial services, including credit assessment, fraud detection, risk management, and personalized financial services [1], [2]. Buy Now Pay Later (BNPL) is one such digital financial innovation that allows consumers to buy products right away with the ability to pay for them in installments. The automated credit assessment and fast eligibility checks offered by AI can be beneficial for providers, helping expedite the lending process and improve its ease [3], [4] another hallmark of BNPL services. With the increasing popularity of BNPL, the focus is now shifting from adoption to understanding the reasons behind the continued use of these services by consumers.

This is particularly important because automatic credit decisions may seem to be "black box" decisions. Consumers may get an approval, rejection, or a credit-related outcome without being aware of the factors or the reason for the result [1], [5]. To overcome this, Explainable Artificial Intelligence (XAI) aims to make the decisions made by AI more understandable and interpretable to humans [1], [6]. Perceived explainability, on the consumer side, is the degree of transparency and/or meaning of the reasoning behind an AI decision that users think is understandable [6], [7]. Previous research has linked users to positive impressions of AI systems when they find their explanations to be understandable, such as trust, acceptance, perceived usefulness, and intentions to use AI in decision-making [7]. But relatively little has been paid attention to regarding post-adoption continuance intention, especially in credit decision making on AI-assisted BNPL.

Users' reactions to credit decision explanations could also be influenced by financial literacy. Financially knowledgeable con-

sumers might be more capable of understanding the repayment demands, loan terms and other factors that relate to the use of BNPL [8]. Thus, perceived explainability could be a boundary condition of the relationship between these two. However, this is an under-researched aspect in the Sri Lankan BNPL landscape, where digital financial services and instalment payments have grown [9]. The present study hence explores the relationship between perceived explainability of AI credit decisions to continuance intention to use the BNPL services and the impact of financial literacy on this relationship. Theoretically, ECM is adopted to interpret post-adoption behaviour, but not in its original form as it is not tested in this study. The study extends explainable AI research to the continued use of BNPL and looks at financial literacy as a potential moderator of consumers' reactions to the explainable credit decisions.

Based on these gaps, the study addresses two questions: whether perceived explainability of AI credit decisions is associated with continuance intention to use BNPL services, and whether financial literacy moderates this relationship. Accordingly, the study aims to examine this association and assess the moderating role of financial literacy. Empirically, the study provides evidence from Sri Lankan BNPL users, while practically, it offers insights for BNPL providers and financial service developers in designing clearer and more understandable AI-supported credit decision processes.

2 LITERATURE REVIEW

2.1 *Theoretical foundation*

The Expectation-Confirmation Model (ECM) [10] The major behavioural lens for this study is the Expectation-Confirmation Model (ECM) [10]. According to ECM, information-system continuance is a post-adoption process that occurs after the initial use of a system in which the information system users assess their experiences with the system. For the original model, factors of central importance to the continuance intention are confirmation, perceived usefulness, and satisfaction [10]. Not all these constructs are measured or tested in the present research. Rather, ECM is seen as being part of a larger theory that post-adoption studies of a digital service are relevant to users' intentions to keep using the service. For BNPL, consumers repeatedly face decisions around eligibility and credit; thus, their perception of how intuitive and understandable the decisions are may be integral to the entire BNPL post-adoption experience.

The study also adopts the Fairness, Accountability, Transparency, and Explainability (FATE) lens to gain an understanding of the conceptual significance of explainability in responsible AI. In the context of FATE, research has focused on enabling users to understand the foundations of consequential automated decisions, and to make explainability a part of more accountable and trustworthy AI systems [1], [11]. In financial services, this concern becomes especially important with algorithmic credit decisions impacting payment and borrowing opportunities. The two perspectives are therefore complementary: FATE argues that explainability is important in AI-assisted decision-making, while ECM offers a lens to reflect on the explanation's influence on the favorability of the decisions made, which might be linked to continued service use. This positioning refrains from using FATE as a behavioural continuance theory or from empirically testing the whole ECM in this study.

2.2 *Explainable AI and perceived explainability*

The need for XAI came in part due to the lack of transparency in complex AI and machine-learning systems, which are sometimes referred to as ‘black boxes' [1] as they may lack a readily available explanation of the underlying process behind their predictions or classifications. This opacity is important in contexts like finance, where users might want to know the rationale behind a credit-related decision. The concept of XAI can be broadly defined as the various approaches that seek to make automated decision-making processes more interpretable, and the concept of perceived explainability specifically considers the user's subjective perception of the understandability and meaningfulness of the explanation [6], [7]. An available explanation is not always a good explanation from the consumer's point of view.

Previous studies have shown that explanations can influence users' perceptions of AI systems. Previous research and perception studies show that the ability to provide

explanations boosts trust, acceptance, perceived usefulness, and the tendency to trust an AI-backed decision [6]. The findings are applicable to BNPL, as consumers might be subjected to automated eligibility checks or credit checks multiple times in instalment payments. If the user can understand the key reason given around these decisions, they can make a more favorable assessment of the service. The present study does not test a specific technique of XAI or technical transparency of a particular algorithm, but rather investigates consumer perception of their understanding of the AI-based decision on lending. Perceived explainability is thus considered to be a construct on the user level, which can be evaluated in terms of post-adoption behavior.

2.3 *Perceived explainability and continuance intention (H1)*

Perceived explainability might be important for continued use, as credit decisions that are understood by customers will lower uncertainty and allow consumers to evaluate the automated process. Earlier research has found a link between understandability of explanations of AI decisions and positive attitude toward AI, as well as acceptance and use of AI-based tools [6], [7]. In BNPL services, customers can experience multiple instances of automated credit decisions as they request installment payment. Similarly to the post-adoption principles of ECM, positive evaluation of the process could be connected with continued usage intentions [10]. Therefore, when the customer perceives AI credit decisions as understandable and meaningful, he/she would report greater continuance intention.

H1: Perceived explainability of AI credit decisions is positively associated with consumers' continuance intention to use BNPL services.

2.4 *Moderating role of financial literacy (H2)*

Financial literacy is defined as an individual's competence in financial terms and the use of financial information for decision-making [8]. In the case of BNPL services, financially literate customers can be in a better position to appraise their debt requirements, credit terms, and information provided with the help of the automated lending decision. Thus, it is hypothesized that financial literacy acts as a moderator and alters the magnitude of perceived explainability on continuance intention. It is likely that financially literate consumers will extract higher benefits from an understandable explanation, while consumers with lower financial literacy can face difficulties evaluating the financial meaning of the information provided. Existing studies on BNPL services underscore the importance of financial knowledge in using such services responsibly [8]. Therefore, financial literacy is considered a potential boundary condition in the study.

H2: Financial literacy moderates the relationship between perceived explainability of AI credit decisions and continuance intention to use BNPL services.

2.5 *Conceptual framework*

The conceptual framework positions perceived explainability of AI credit decisions as the predictor of continuance intention and financial literacy as the moderator of that relationship.

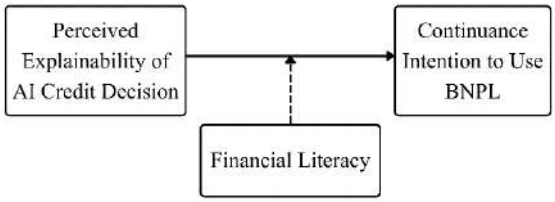


Figure 1. Conceptual framework

3 METHODOLOGY

A quantitative cross-sectional survey design was adopted to explore the relationship between the perceived explainability of AI credit decisions and continuance intention and to test the moderating effect of financial literacy. The target population included Sri Lankan consumers who had previously interacted with e-commerce products that relied on buy now pay later financing (BNPL) like Koko, MintPay, and Payzy. Convenience sampling was used. The questionnaires were collected, with a total of 417 questionnaires, of which 404 questionnaires were valid after data screening and cleaning were performed. The cross-sectional design can be used to study relationships (statistical associations) between the study variables.

The analytical sample included respondents aged 25–34 years (47.2%), 18–24 years (46.8%), 35–44 years (4.7%), and 45–54 years (1.2%). Most respondents were undergraduates (60.1%), followed by the postgraduates (17.3%). The most common BNPL application reported was Koko (80.4%), followed by MintPay (33.9%) and Payzy (8.9%); respondents could report more than one application. In terms of frequency of use, 33.9% had only tried BNPL apps for less than six months, while 30.9% had used the apps for six months to a year, 23.8% for one to two years, and 11.4% for over two years.

The data were gathered using *a* structured, self-administered questionnaire that uses measures adapted from the literature. We measured perceived explainability using five items related to the concept of explanation adapted from [12]and reworded for the context of AI-supported BNPL credit decisions. Continuance intention was measured with three items adapted from [10]. The two of these constructs were measured on seven-point Likert scales where 1 equals Strongly Disagree and 7 equals Strongly Agree. Financial literacy was assessed by three objective knowledge questions which was adapted from [15] and a score was determined based on the number of correct answers. Descriptive, reliability, factor, correlation and regression analyses were conducted using IBM SPSS Statistics, and a moderation analysis was conducted using Hayes' PROCESS Macro.

3.1 *Data analysis and measurement assessment*

Before hypothesis testing, the data were examined for normality, reliability, construct validity, and potential common-method variance. The skewness values ranged from −0.938 to −0.513, while kurtosis values ranged from −0.789 to 1.672, indicating no substantial departure from normality. Internal consistency was assessed using Cronbach's alpha. Perceived Explainability (α = 0.896), Continuance Intention (α = 0.791), and Financial Literacy (α = 0.717) all exceeded the commonly accepted minimum threshold of 0.70, indicating satisfactory reliability.

Construct validity was assessed for the perceptual measures, Perceived Explainability and Continuance Intention, using Exploratory Factor Analysis (EFA). Principal Axis Factoring with Direct Oblimin rotation was applied. The Kaiser–Meyer–Olkin measure was 0.896, while Bartlett's Test of Sphericity was statistically significant, $\chi^2(28) = 1677.139$, $p < 0.001$, confirming the suitability of the data for factor analysis. Two factors were extracted, jointly accounting for 61.19% of the variance. Factor loadings ranged from 0.707 to 0.857 for Perceived Explainability and from 0.673 to 0.817 for Continuance Intention, supporting the expected two-factor structure.

Table 1. Measurement assessment summary

Measure	Items	Cronbach's α
Perceived Explainability	5	.896
Continuance Intention	3	.791
Financial Literacy	3	.717

Common-method variance was also examined because the perceptual measures were collected from the same respondents through a self-administered questionnaire at a single point in time. Harman's single-factor diagnostic showed that a single factor explained 56.76% of the total variance. Since this value exceeds the commonly used 50% diagnostic threshold, common-method variance cannot be completely ruled out. Therefore, the result is not interpreted as evidence that common-method bias is absent; instead, it is acknowledged as a methodological limitation of the study. At the same time, the two-factor EFA showed that Perceived Explainability and Continuance Intention emerged as empirically distinct constructs in the dataset. Accordingly, the findings are interpreted cautiously, and no causal claims are made.

3.2 *Correlation and hypothesis testing*

Pearson correlations showed that Perceived Explainability was positively associated with Continuance Intention ($r = .566$, $p < .001$). Perceived Explainability also had a weak positive association with Financial Literacy ($r = .127$, $p = .010$), while Financial Literacy was positively associated with Continuance Intention ($r = .172$, $p = .001$). These relationships provide preliminary evidence of association among the study variables but do not establish causality.

Table 2. Correlation matrix

Variable	1	2	3
1. Perceived Explainability	1.000		
2. Continuance Intention	.566**	1.000	
3. Financial Literacy	.127**	.172**	1.000

Note: *p < .05; **p < .01.

H1 was tested using simple linear regression. The model was statistically significant, $F(1, 402) = 189.028$, $p < .001$, with $R^2 = .320$ and adjusted $R^2 = .318$. Perceived Explainability was positively associated with Continuance Intention ($B = .354$, $SE = .026$, $\beta = .566$, $t = 13.749$, $p < .001$). Thus, H1 was supported. H2 was tested with PROCESS Model 1. The overall moderation model was significant, $F(3, 400) = 65.809$, $p < .001$, $R^2 = .3305$. Perceived Explainability remained significant ($B = .3461$, $p < .001$), and Financial Literacy showed a positive direct association with Continuance Intention ($B = .2028$, $p = .0145$). However, the PE × FL interaction was not significant ($B = -.0112$, $SE = .0229$, $t = -.4889$, $p = .6252$, 95% CI [-.0562, .0338]), and the interaction added only $\Delta R^2 = .0004$. Therefore, H2 was not supported.

Table 3. Hypothesis-testing summary

Hyp.	Term	B	SE	p	Decision
H1	PE → CUI	.354	.026	<.001	Supported
H2	PE × FL → CUI	−.0112	.0229	.6252	Not supported

H1 model: R^2=.320. H2 moderation model: R^2=.3305; interaction ΔR^2=.0004.

4 FINDINGS AND DISCUSSION

The results support H1 and show that perceived explainability of AI credit decisions is positively associated with continuance intention to use BNPL services. Considering the study sample as a whole, the variance in continuance intention was explained by perceived explainability alone (32.0%), which was considered significant. Those who said the AI-powered credit decisions were more understandable also showed greater plans to use BNPL more. This result aligns with previous studies that demonstrated the positive correlation between explainability and positive user attitudes towards AI, such as acceptance, perceived usefulness, and reliance on automated systems [6], [7]. An understandable explanation can assist users to make sense of repeated interactions with credit and potentially minimize the amount of uncertainty about an automated eligibility decision in a BNPL environment.The result is also coherent with the post-adoption rationale of ECM [10]. ECM suggests that first-time evaluations by users are pertinent to continuance behaviour. In the present study, the relationship we observed suggests that explainability can be regarded as a relevant post-adoption experience attribute of BNPL services using AI.

H2 was not supported. There was no significant moderation effect between perceived explainability and continuance intention (R^2 change was less than 1%), and the interaction term did not significantly contribute to the model. Within the observed sample, the association between explainability and continuance were not significantly different by financial literacy. But the result does not suggest that financial literacy is not important. In the moderation model, financial literacy had a strong positive association with the intention of continuing the BNPL service, supporting the idea that it could have a moderating effect on consumers' attitudes toward BNPL use in general. But the association between perceived explainability and continuance intention remained the same, irrespective of the level of financial knowledge. A possible explanation is that explanations which are understandable for the credit decision made by AI might be relevant for users with varying degrees of financial literacy. The need for explanation to make decisions about continuance intentions may not be significantly different for highly literate consumers and consumers with limited financial knowledge, and clear communication of why a decision was reached may have value for both groups. This should be interpreted with caution since the interaction was not significant. Future studies might explore the possibility of replacing the general financial literacy boundary condition with AI literacy, digital financial literacy, complexity of explanation, or the type of credit outcome.

5 MANAGERIAL IMPLICATIONS

The results have practical implications for BNPL service providers, financial institutions, and developers of AI-based credit decision-making systems. In light of the positive association between perceived explainability and the willingness to continue using the service, providers should clearly communicate the automated credit decision to users. Instead of providing just the credit decision outcome (approved or rejected), the interface should provide an explanation of what are the key criteria used in the decision, its interpretation and, when necessary, information about repayment or eligibility requirements. Explanations should not contain unnecessary jargon and should take into account different levels of consumers' financial literacy. In view of the lack of a moderating effect, understandable explanations should not target solely financially literate users. On the other hand, the positive direct association between financial literacy and the continuance intention indicates that financial education and transparency in explaining instalments is beneficial overall.

6 LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

There are some restrictions to be considered. Firstly, the cross-sectional survey design allows for statistical associations to be examined, but not for causal relationships or changes in perceptions over time. To test the effects of different explanation designs and temporal ordering more directly, longitudinal or experimental research could be conducted. Second, convenience sampling and the inclusion of local Sri Lankan BNPL users reduce the ability to generalize to other populations, markets, and digital-credit environments. Samples from different probability samples or cross-country comparisons could be used in future studies.

Third, common-method variance cannot be completely excluded, as the perceptual variables were measured with the same respondents at the same time. Further study might be done to partition measurements temporally, multiple data sources could be used, or statistical controls could be applied more rigorously. Fourth, this study concentrates on perceived explainability, financial literacy, and continuance intention. Some variables like trust, perceived fairness, perceived risk, AI literacy, satisfaction, and perceived usefulness may be incorporated to examine more complex behavioural mechanisms and more comprehensive theoretical models. The reliance on just three objective financial-literacy indicators is another reason to consider other indicators of consumers' financial capability in future research.

7 CONCLUSION

The current research focused on how the perceived explainability of AI credit decisions is linked to consumers' continuance intention to use BNPL services and explored financial literacy as a moderator among Sri Lankan BNPL users. The perceived explainability was significant and positively correlated with continuance intention, and the interaction between perceived explainability and financial literacy was not significant. Financial literacy therefore did not moderate the focal relationship. The study extends existing explainable-AI literature towards post-adoption behaviour and shows the importance of users' understanding of automated credit decisions in the BNPL context. The findings also highlight the need to differentiate between observed associations and causal claims and to differentiate the current results from unmeasured mechanisms like trust. The findings support the notion that perceived explainability is a relevant correlate of BNPL continued use intentions, and provide a foundation for additional studies based on a longitudinal design.

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An Exploration of How AI-Generated Visuals Shape Creative Practices of Illustrators in Sri Lankan Print Media

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ABSTRACT: This study explores how AI generated visuals are shaping the creative practices of illustrators working in Sri Lankan print media, with special focus on Colombo District based organizations. The rapid growth of artificial intelligence tools has created many changes in creative industries around the world. However, there is limited research about how these changes are experienced by illustrators in Sri Lanka, especially in print media environments. The central question guiding this research is: How do AI-generated visuals shape the creative practices of illustrators in Sri Lankan print media? The study aimed to understand how illustrators use AI tools in their daily work, how AI affects creativity and originality, and how creative workflows are changing. The study used a qualitative research approach. Data was collected through twelve semi structured interviews and one focus group discussion with professional illustrators and graphic designers working in print media organizations in Colombo District. Illustrators were selected using purposive sampling because they had direct experience with AI-generated visual tools. The collected data was analyzed using thematic analysis, guided by Sociotechnical Systems Theory. The findings showed that AI is mainly used as a support tool rather than a replacement for human creativity. Most Illustrator used AI during idea generation, concept development, and reference searching because it helps save time and improve efficiency. At the same time, Illustrator said that human skills, creative thinking, and final editing are still very important for professional quality work. Many Illustrators also explained that too much dependence on AI may reduce original thinking and deep creative exploration. Another important finding was that AI tools often struggle to accurately represent Sri Lankan cultural elements, traditions, and local visual identity. Because of this, designers still need to manually correct and improve many AI generated outputs. Illustrator also shared mixed views about authorship and ownership, but most felt that ownership remains with the designer when the original concept and direction come from the human creator. Overall, the study concludes that AI is changing the creative practices of illustrators in Sri Lankan print media in both positive and challenging ways. AI works best when it supports human creativity rather than replacing it. The study contributes to a better understanding of AI use in Sri Lanka's creative industry and may be useful for designers, educators, organizations, and future researchers.

Keywords: AI-generated visuals, creative practices, illustrators, print media, sociotechnical systems theory

1 INTRODUCTION

Illustration is a form of visual art that plays an important role in printing media such as books, magazines, newspapers and advertisements to convey a message, support storytelling, or communicate an idea within visuals. Illustrators are creative professionals who are responsible for creating these art works. An illustrator should have a level of

creativity, originality, idea generation, concept thinking, imagination, and work experience to generate a successful creative outcome. Creative practice in illustrator is not only about artistic talent; but also, about the process of researching, idea development, making decisions and feedback.

Creativity, commonly defined as the ability to generate novel and useful ideas [5]. Several scholars define creativity as a "human-specific capability which requires conscious thinking and strong emotions and the power of transforming the world" [8].

With the advancement in technology, AI power has been developed to generate visuals in seconds. In recent years, the use of AI generative tools in creative industries, including print media, has rapidly increased. Creative professionals also started to use AI visual generative tools to support their idea of generation, research, and concept development. According to Caramiaux et al. [2], the creative process is time consuming and inefficient for artists and creatives. Many professional designers use these AI visual generative tools to manage their time on predesign stage as an idea generation or a reference tool to explore new ideas and meet deadlines.

Supporters of AI generative tools argue that AI improves the creative practices of a designer because of the wide data base. According to the CEO of Picsart "I really see it more like a copilot to allow humans to be even more creative and more advanced in their expression. So, the things which were taking years of learning and training and fine tuning, now you can do it easier and faster. It's opened an opportunity for more people to be creative." According to Caramiaux et al. [2]. However, other researchers argue that AI visual generative tools rely on existing databases and repeat the visual elements and styles through artworks which reduce the uniqueness, originality, and creativity of an outcome. Additionally, scholars raise concerns about copyright, creative control, and lack of emotional depth in AI-generated art.

In Sri Lanka the use of AI visual generative technology is still in the emerging state. Print media organizations as well as freelance designers, especially in Colombo District, are slowly adapting to these technologies. This was proved by a researcher in an empirical study based on content analysis of 279 Sri Lankan public listed company's annual reports. It found out 26 companies mentioned their plan of using AI. Colombo has become a central hub for publishing houses and advertising agencies. Therefore, it makes a suitable place to study the impact of AI generative visuals on professional illustrators in print media specifically.

Ideally, The Sri Lankan professional illustrators in print media should be able to express their creative ideas with freedom in their artworks and this was expected to be an original, personalized idea with emotional depth and human expressions. In an ideal situation, the AI visual generative technology should be a supportive tool or the illustrator to idea generation or influence without overtaking creative control. Previous study shows that AI generative tools can be a supporting tool rather than a replacement. [5]. However, in reality the rapid increment of AI generative visual tools began to reshape the roles of creative professionals. Many designers use these tools to improve the speed of work and efficiency. Previous studies show that overuse of AI visual generative tools can be affected by design fixation, creative thinking, and originality. [7]. And some designs may contain similar elements and repeated patterns.

From the perspective of Sociotechnical system theory, creative practices are based on interaction between social systems and technological systems. In this situation, the social systems are skills, emotions, creativity, values and knowledge of illustrators, and the technological systems are visual generative artificial intelligence software and workflow. The problem emerges when the technological systems begin to overly influence the creative process of decision making without the user knowing. Therefore, it is necessary to explore the impact of AI generative visuals on the creative practices of illustrators in the Sri Lankan print media.

This paper is organized around a single, central research question that reflects the main research question of the original study:

"How do AI-generated visuals shape the creative practices of illustrators in Sri Lankan print media?" This study helps to understand how AI generated visuals shape the creative practices of illustrators in the print media sector in Colombo District, Sri Lanka. The findings of this research will be important for professional illustrators currently working in print media, for print media organizations seeking to understand the

creative risks of using AI generated visuals without clear guidelines, and for design education preparing future creative professionals to work with developing technologies. The study will also contribute to existing literature on AI generative visuals and creative practices of illustrators by providing empirical evidence from a Sri Lankan context, filling an important gap by adding local knowledge to international research.

The study is conducted to professional illustrators with at least one year of experience working in Colombo District print media organizations which were selected through purposive sampling. It focuses specifically on printing related creative work such as book covers, magazine covers, story book art, advertisement posters and does not extend to newspaper layout or typographic page design or illustration produced solely for digital media.

2 LITERATURE REVIEW

The rapid development of artificial intelligence has brought significant changes to creative industries. This literature explores the existing knowledge of AI generative visuals and their impact on creative practices and how artificial intelligence shapes the creative process of illustrators in the print media industry. The chapter review is organized around Sociotechnical System Theory as the main framework which provides an understanding of how technology and human creativity interact together.

In recent years, artificial intelligence has transformed from being primarily a research topic to becoming a practical reality in many creative fields. Anantrasirichai & Bull [5] explained if AI has entered industries like design, music, filmmaking and visual arts and they explained that AI was mainly used for automation and repetitive tasks but now AI was developed to generate visuals, music and content writing. [5]. This shows 0 that currently AI is not only a tool to support work, but it also creates creative output by itself. This system is what makes AI more developed. [5]. The rise of generative text to visual AI systems represents a major milestone in AI history, and these tools are adapted in creative industries because they save time for the design process and make it easier for the designer to research and develop ideas. [6].

Caramiaux et al. [2] expand this discussion by looking at how AI changes the narratives and values within creative organizations. Their research findings reveal that when AI tools were introduced to the creative work, they show changes in the creative control, idea generation, and output quality rather than artistic value. This may result in gradually shifting designers from traditional creative processes to AI managed processes. If the focus moves too much toward managing AI systems, there's a risk that traditional creative skills and human decision making might be undervalued. These discussions connect directly with the framework of this study. Sociotechnical system theories explain that technology and social systems are always connected. Bostrom and Heinen [2]. Adaptation of AI generated visuals techniques to the industries in in the creative practice of a designer will not disappear or replace, but it can reshape the process. [7].

According to Fu et al. [6], generative AI does not consistently affect all users' inherent creativity, but it does improve first-time generative AI users' divergent thinking as measured by idea fluency and flexibility. Other researchers, however, caution that AI visual generative tools rely on existing databases and repeat visual elements and styles across artworks, which can reduce uniqueness, originality and creativity in the outcome.

Previous research of Deckker & Sumanasekara [8] shows that AI image generation often struggles to represent Sri Lankan cultural identity properly. Their research reveals that AI systems typically train on predominantly western data sets because of this when users use AI tools to generate Sri Lankan visuals the outputs often fail to accurately represent Sri Lankan, cultural elements, visual, aesthetics, and social context. This creates a challenge for illustrators who want to use AI while keepkeepg cultural accuracy. In Sri Lankan, creative words AI cannot perform individually. The outputs need human guidance to adjust, colour symbols and design details to reflect the cultural impact. [8].

Understanding the organizational context of Print media in Sri Lanka is highly concentrated in Colombo the Department of national archives of Sri Lanka [13] shows that most printing processes are located in Colombo District because of this illustrated working in Colombo District usually walk in

more structured organizations which they may have been better access to technologies, professional networks and industry opportunities at the same time they also faced stronger competition and higher productivity expectations. According to Pasqual [14] Sri Lankan newspaper productions follow a strict editorial system that likely influences visual content production as well newspapers, and operates under deadline pressures, editorial guidelines, and commercial considerations.

This literature review identifies several significant gaps that support the need for this study. Most existing research examines AI's impact on creative work in Western, developed-country contexts, with minimal research addressing developing-country contexts like Sri Lanka, where factors such as technology access, internet infrastructure, workplace culture, professional standards, and organizational structures may influence how AI generative visuals are used in creative work. Existing studies also tend to focus on design professionals in general, with limited research explaining the illustrator's perspective, particularly those in traditional media industries such as magazines, book illustrations, and poster design. Many existing studies also use experimental or quantitative research methods, which, while valuable for establishing general patterns, provide limited insight into the personal experiences of creative professionals. Finally, the combination of AI generated visuals, professional illustrators, print media organizations, and the Sri Lankan context has not been widely studied, and this study aims to fill this knowledge gap by exploring these relationships through empirical research.

Sociotechnical system theory was first developed by researchers at the Tavistock institute in the 1950s and 1960s. The researchers studied the workplace and found that many new technologies did not give the expected results. The main reason was that the organization focused too much on the machines and systems rather than human aspects and social connections. The theory explains that every organization has two main parts, such as technical subway systems and social subway systems. The technical subway system includes tools, machines, technologies, work processes, and physical equipment in this research the tactical subsystems means AI visual, generative tools, digital illustration, software, computers, and other hardware used by illustrators the social subway system includes the people the employers their skills, knowledge attitudes, their practices, professional identities, their workflow, the teamwork, the management structures, values, and organizational culture cultures. Bostrom and Heinen [2] applied sociotechnical systems theory applied sociotechnical systems theory to information systems, establishing principles that remain relevant to AI systems today, arguing that many system failures happen because there is a mismatch between technology and real workplace conditions. Recent research by Storey et al. [10]. applies this framework directly to generative AI, describing generative AI as reshaping work practices rather than replacing them, creating new forms of coordination while also generating new tensions and opportunities around data privacy, copyright, authorship transparency, and ethical decision making.

3 GETTING STARTED

This study used a qualitative research approach because it aimed to understand the personal experiences, opinions, and creative practices of illustrators and related creative professionals. The research design was guided by Sociotechnical Systems Theory. A qualitative approach was suitable because the study focused on experiences and interactions rather than numerical measurement.

Purposive sampling was used to select participants with direct relevance to the research topic.

Participants met the following criteria: (1) they were working professionally in or were directly connected to Sri Lankan print media; (2) they had at least one year of professional experience; (3) they had experience or exposure to AI-generated visual tools through direct use or professional awareness; and (4) they were willing to participate and provide informed consent. Twelve participants took part in semi-structured interviews. A separate group of five participants took part in one focus group discussion.

Therefore, the study involved 17 participants in total. The focus group participants were not part of the twelve interview participants.

The twelve interviews were selected based on the principle of data saturation.

Saunders et al. [11] discuss saturation as a point at which additional qualitative data provide limited new insights. The interviews were the primary data collection method and explored individual experiences, opinions, and creative practices. After the interviews were analyzed, the focus group discussion was conducted to examine and confirm patterns and themes identified from the interview data. The focus group therefore functioned as a validation and comparison stage rather than as a replacement for the interviews.

Ethical considerations were addressed before data collection. Participants were informed about the purpose of the study, the voluntary nature of participation, and their right to withdraw. Informed consent was obtained before participation.

Participants were not identified by their personal names in the paper. Participant codes such as P1 to P12 were used for the interview data, and the focus group participants were reported collectively to protect confidentiality. Audio recordings and transcripts were handled for research purposes only.

The qualitative data were analyzed using thematic analysis following the six-step framework of Braun and Clarke [12]. Interview and focus group data were first analyzed separately. The researcher transcribed the recordings and repeatedly read the transcripts to become familiar with the data. NVivo was used to organize, manage, and code the qualitative data. Initial coding was performed separately for interview and focus group data to identify similarities and differences. The NVivo codes were then reviewed by the researcher, compared across the two datasets, grouped into related concepts, and refined manually. The final themes were therefore developed through researcher-led interpretation of the NVivo-organized coded data, rather than by discarding the NVivo analysis. The focus group findings were used to confirm, clarify, or challenge patterns identified in the interview data.

The analysis was also informed by Sociotechnical Systems Theory. Findings were considered in relation to social system factors such as emotions, professional identity, creative confidence, skills, and originality; technical system factors such as AI tools, prompt writing, workflow changes, speed, technical limitations, and efficiency; and social tensions such as concerns about human creativity, AI suggestions, over-dependence, and design fixation.

3.1 *Participant Profile*

Table 1 provides a summary of the participant groups and professional context. All interview participants met the minimum one-year professional experience criterion. The reported AI experience below refers to the approximate period of AI use or exposure where this information was recorded during participant selection.

Table 1. Participant profile

Code	Role	AI Use
P1	Manager	2 years
P2	Graphic designer	1 year
P3	Graphic designer	2 years
P4	Graphic designer	Since 2023
P5	Graphic designer	1 year
P6	Senior Illustrator	2 years
P7	Graphic designer	2 years
P8	Illustrator	2 years
P9	Graphic designer	2+ year
P10	Art Dirrector	1.5 years
P11	Graphic designer	2 Years
P12	Graphic designer	2 Years
FGD	Five participant from creative design and illustration roles	Varied

* Note: Exact personal names were not reported. Participant codes were used to maintain confidentiality. The five focus group participants were separate from the twelve interview participants.

4 RESULTS

Twelve semi-structured interviews were conducted with professional illustrators and graphic designers, while five separate participants joined the focus group discussion. The participants included in-house designers, illustrators, a freelance creative designer, a storybook illustrator, and other creative professionals connected to print media in Colombo District. Thematic analysis of the interview and focus group data produced five main themes.

The first theme, human-AI interaction and creative thinking, showed mixed views about whether AI expands or limits creativity. P1 explained that AI is used as a support tool and that users must guide it. Some participants felt AI opened new directions for ideas, while others were concerned that excessive use could reduce critical thinking.

P12 described the general position as being influenced rather than dependent, with final decisions remaining with the designer.

The second theme, workflow transformation, showed that AI mainly saves time during reference gathering and idea generation. P3 explained that AI can reduce the time needed to obtain visual references through prompts. Participants also stressed that AI was normally used at particular stages rather than for the complete final design.

Technical limitations were noted, including the need for further preparation of outputs for print requirements such as CMYK and final file preparation.

The third theme, creative control, authorship, and professional identity, found that participants generally connected ownership with the human contribution to the concept, direction, prompting, editing, and final design. However, participants also recognized that ownership becomes more uncertain when a designer simply copies an AI-generated result with little modification. Some participants were concerned that AI could make it easier for less experienced users to produce work that appears similar to professional work.

The fourth theme, collaboration and communication, showed that awareness of AI use varied among clients and workplaces. Participants described differences in organizational attitudes, with some workplaces encouraging AI use and others restricting it because of concerns about originality or professional standards.

The fifth theme, organizational influence and cultural context, revealed concerns about the accuracy of Sri Lankan cultural representation. Several participants said that AI-generated outputs could contain visual elements associated with other cultural contexts, including Indian visual influences. Participants therefore reported that manual correction was often required. Time, deadlines, and cost pressures were also described as factors influencing AI adoption.

Across the five themes, the findings show that AI is changing illustration work through a combination of benefits and challenges. Benefits include faster idea generation, reference searching, and workflow efficiency. Challenges include originality, cultural representation, professional identity, technical print requirements, and possible over-dependence.

5 DISCUSSION

The findings show that AI is mainly used as a supporting tool during pre-production rather than as a complete replacement for the illustrator.

Participants described using AI for reference gathering, suggesting directions, and developing concepts. From a sociotechnical perspective, this shows an interaction between technical capabilities and the skills, values, and decisions of the illustrator. AI becomes part of the workflow, but human judgement remains important.

Influence versus dependency was an important part of the findings. Participants explained that AI use can increase when deadlines are tight because it saves time. Under less time pressure, participants described using AI more selectively for reference and idea exploration. This suggests that the level of AI influence is affected not only by the technology itself but also by workplace conditions such as deadlines, workload, and organizational expectations.

The study also found that AI changes parts of the workflow without fully replacing the illustrator's work. AI-generated visuals often require further editing, refinement, and technical preparation before they can be used in print. Print work also requires appropriate resolution, colour settings, file preparation, and other production adjustments.

Therefore, human skills remain important in producing final professional outputs.

Participants had different views about authorship and ownership. Many connected ownership with the person who develops the original concept, directs the work, provides the prompts, and performs the final editing. However, some participants considered ownership unclear when AI-generated material is used with little human modification. This finding suggests a need for clearer organizational guidance about AI-assisted creative work.

Cultural representation was another important issue. Participants reported that AI-generated visuals could mix Sri Lankan cultural elements with visual characteristics associated with other countries. This means that AI can save time during early creative stages but may also create additional corrective work when cultural accuracy is important. The finding supports the importance of examining AI use in local cultural con-

texts rather than assuming that findings from other countries will apply directly to Sri Lankan print media.

Organizational context also influenced AI use. Some organizations encouraged AI because it could help meet deadlines and manage costs, while others were more cautious because of concerns about originality and professional standards. This supports the sociotechnical view that technology cannot be separated from the organizational environment in which it is used.

Overall, the answer to the research question is that AI-generated visuals shape the creative practices of Sri Lankan print media illustrators mainly by changing pre-design activities, idea development, reference gathering, and workflow speed. At the same time, AI introduces concerns about originality, authorship, professional identity, cultural accuracy, and over-dependence. The level of influence varies according to the individual, the task, and the workplace context.

5.1 *Practical Implications*

For illustrators, AI can be used as a support tool while maintaining human control over concepts, decisions, editing, and final outputs.

For print media organizations, clear internal guidelines can help employees understand when and how AI-generated visuals should be used, especially when cultural accuracy, originality, and client requirements are important.

For design education, students can continue to develop creative thinking, sketching, concept development, and visual decision-making skills alongside AI literacy. This can help future designers use AI as part of a broader creative process.

For future researchers, longitudinal studies and comparisons between different types of print media organizations could examine how AI use changes over time and how workplace conditions influence adoption.

6 CONCLUSION

This study explored how AI-generated visuals shape the creative practices of illustrators in Sri Lankan print media. The findings show that AI is mainly used as a support tool for idea generation, reference gathering, concept development, and saving time. However, participants also identified concerns about originality, cultural representation, authorship, technical print requirements, and possible over-dependence. The findings demonstrate that the influence of AI is shaped by both technical capabilities and social factors such as human skills, professional values, workplace conditions, and organizational rules. Therefore, AI-generated visuals are becoming part of the creative workflow of Sri Lankan print media professionals, but human judgement and creative skills continue to play an important role in the final work.

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