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Editorial

Information Management and Business Review (IMBR) provides a digital forum for researchers to share their knowledge and publish research work in the fields of information management, business, management and related disciplines. The work submitted for publication consideration in IMBR should address empirical and theoretical developments in the subjects related to the scope of the journal in particular and allied theories and practices in general. Author(s) should declare that work submitted to the journal is original, not under consideration for publication by another journal and that all listed authors approve its submission to IMBR. It is IMBR policy to welcome submissions for consideration, which are original and not under consideration for publication by another journal at the same time. Author (s) can submit: Research Paper, Conceptual Paper, Case Studies and Book Review. The current issue of IMBR comprises papers of scholars from different universities of Malysia, China and Indonesia. E-Customer Relationship Management and Customer Loyalty in the Context of Logistics Service Providers, Relationship Between Supply Chain Integration, Green Supply Chain Management Practices and Sustainability Performance, Theoretical Framework for Student Health-Related Quality of Life, EcoTacToe Digital Gamification In Education, Evaluating Consumer Acceptance of Medical Repricing, Assessing Students' Conceptual Understanding of an Islamic Financial System, Effectiveness of Gamified Augmented Reality in Higher Education, Islamic Debt Principles, Generation Z's Behavioral Intention Towards Festival Events, Redefining Human Capital Sustainability, Learner Readiness and Expectations for Metaverse-Based Education, EcoBytes: Enhancing Teaching and Learning in Economics, Factors Influencing Consumer Buying Behavior for Foreign Products, Knowledge-Based and Social Determinants of Environmental Performance, Mapping the Global Trends and Thematic Evolution of Big Data Analytics Capabilities Research, The Role of MOOC-Based Supplementary Learning in Enhancing Student Academic Performance, Nexus of Financial Literacy and Cashless Payment Adoption, The Green Practices Outcome on Sustainability Performance, FinTech Financing Platforms and Bank Lending to SMEs & Integrating the Theory of Planned Behavior and the Norm Activation Model are some of the major practices and concepts examined in these studies. All the submitted papers were first assessed by the journal committee and then the external editorial team for relevance and originality of the work and then blindly peer-reviewed by external reviewers depending on the subject matter of the paper. After the rigorous peer-review process, the submitted papers were selected based on originality, significance and clarity of the purpose. The issue will, therefore, be a unique proposition, where scholars will be able to appreciate the latest results in their field of expertise and to acquire additional knowledge in other relevant fields.

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TABLE OF CONTENTS

Description	Pages
Title	I
Editorial	II
Editorial Board	III
Table of Contents	IV
Papers	VI
E-Customer Relationship Management and Customer Loyalty in the Context of Logistics Service Providers: A Mediating Effect of Customer Satisfaction Soo-Cheng Chuah, Chai-Li Cheam, Jiang Lu, Roslilee Ab Halim, Fei Wan	1
The Relationship Between Supply Chain Integration, Green Supply Chain Management Practices and Sustainability Performance: A Conceptual Framework Norzawani Ibrahim, Nur Najjah Abd Rahim, Norasekin Abd Rashid, Mior Faizmie Yusof Za Ba, Nur Amalina Abd Rahim	14
Modeling The Qualitative Sub-Domains of Sleep Health: A Theoretical Framework for Student Health-Related Quality of Life Liatul Izian Binti Ali Husin, Dilla Syadia Ab Latiff, Noorizan Mohamad Mozie, Norfazlina Ghazali	23
EcoTacToe Digital Gamification In Education: A Cross-Sectional Study Azhan Rashid Senawi, Shariff Harun, Mohammad Zulfakhairi Mokhtar, Husna Husain, Li Shuang, Nik Musri Erwan Eddy Nik Mustapha	31
Evaluating Consumer Acceptance of Medical Repricing in Malaysia: The Role of Fairness, Transparency, Trust and Health Insurance Literacy Mohd Faizol Rizal Mohd Rasid, Ainol Fizy Ruslan, Nurul Hidayah Zainal, Ahmad Al-Amin Faisal, Muhammad Hafiz Marzuki, Nurul Farehah Anuar	37
Assessing Students' Conceptual Understanding of an Islamic Financial System Course Using the Rasch Wright Map Mohd Rahim Khamis, Mohd Faizal Kamarudin, Nur Afizah Muhammad Ariffin, Mohd Faizan Mohd Afandi	52
The Effectiveness of Gamified Augmented Reality in Higher Education: A Case Study of MARA 5.0 in a Public University Abdul Hamid Abdul Halim, Dr Hairulnizam Hashim, Masrur Mohd Khir, Nor Azzura Nordin, Ryan Kang Jee Hong, Natalie Loi Yoke Kei	63
Islamic Debt Principles: A Conceptual Framework for Ethical and Asset-Backed Financing Zahariah Sahudin, Marhani Mohamed Anuar, Hartini Zuhaila Jamal, Heizal Hezry Omar	72
Development and Pilot Validation of an Instrument Measuring Generation Z's Behavioral Intention Towards Festival Events Ayu Rohaidah Ghazali, Wan Soraya Wan Abdul Ghani, Nurakmal Ramli, Norhidayah Mohd Rashid, Nini Hartini Asnawi, Syazwani Mohamad, Muhammad Hafizuddin Mohamad Nazer	83
Redefining Human Capital Sustainability: An Integrative Conceptual Framework Harmonizing ISO 45003 and the Job Demands-Resources Model for Psychosocial Risk Assessment Faizatul Akmam Amirrudin, Norina Ahmad Jamil, Mashitah Mohamed Esa, Faizah Mashahadi, Nurul 'Ain Amirrudin	95
Assessing Learner Readiness and Expectations for Metaverse-Based Education: A Pre-Survey Analysis of EON XR in Healthcare Service Quality Course Mohd Zulkifli Abdullah, Siti Noorsuriani Maon, Zaliza Azan, Elsa Roselina, Intan Akirah Zakri	107
EcoBytes: Enhancing Teaching and Learning in Economics through Short-Form Microlearning Videos J.S. Keshminder, Afiza Azura Mohamad Arshad, Nur Azirah Zahida Mohamad Azhar	119
Factors Influencing Consumer Buying Behavior for Foreign Products Nurfarah Diyana Mohd Firhad, Syed Ashrene Syed Omar, Janiffa Saidon, Nuryusmawati Mohd Yusof, Nor Lelawati Jamaludin, Faizah Md Sohid, Faizah Mashahadi	131

Knowledge-Based and Social Determinants of Environmental Performance Among Young Adults in Klang Valley: The Mediating Role of Green Innovation Practice Dellorinna Icha Anak Tang, Ramita Abdul Rahim, Siti Fazilah Hamid, Nur Fatin Izzati Jeffri	136
Mapping the Global Trends and Thematic Evolution of Big Data Analytics Capabilities Research: A Bibliometric Review Nur Zania Azurin Abdullah Sani, Noor Ismawati Jaafar, Farzana Parveen Tajudeen	151
The Role of MOOC-Based Supplementary Learning in Enhancing Student Academic Performance: Evidence from Non-Business Students in an Entrepreneurship Course Mutiiah Mohamad, Farah Lina Azizan, Syazwani Ya, Wan Nurulasiah Wan Mustapa, Emeela Wae-esor	181
A Bibliometric Analysis on the Nexus of Financial Literacy and Cashless Payment Adoption Nurul Syazwani Mohd Noor, Juliana Arifin, Farah Amalina Md Nawi, Norhidayah Abu Bakar	194
The Green Practices Outcome on Sustainability Performance: Evidence from Malaysian Manufacturing Companies Mashitah Mohamed Esa, Nor Fazilah Mohd Hashim, Mohd Shamsuri Khalid, Tooty Jamaludin	210
FinTech Financing Platforms and Bank Lending to SMEs in Malaysia: Complements or Substitutes Nur'Asyiqin Ramdhan, Rohanizan Md Lazan, Norsaliza Abu Bakar	222
Integrating the Theory of Planned Behavior and the Norm Activation Model to Explain Prosocial Rumor Refutation Erne Suzila Kassim, Hanitahaiza Hairuddin, Sri Fatiany Binti Abdul Kader Jailani, Safwan Kamal	239

PAPERS

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E-Customer Relationship Management and Customer Loyalty in the Context of Logistics Service Providers: A Mediating Effect of Customer Satisfaction

*Soo-Cheng Chuah[1], Chai-Li Cheam[1], Jiang Lu[1], Roslilee Ab Halim[1], Fei Wan[2]
[1]Faculty of Business and Management, Universiti Teknologi MARA, Selangor, Malaysia
[2]School of Digital Economics and Management, Suzhou City University, Wuzhong Avenue, Wuzhong District, Suzhou, Jiangsu Province, China
Email: *chuahsc@uitm.edu.my
Corresponding Author: Dr Soo-Cheng Chuah

Abstract: In the competitive logistics industry, fostering long-term customer relationships is important for sustained business performance. Logistics companies have increasingly adopted digital tools to manage customer relationships and support customer loyalty. This study examines the relationship between electronic customer relationship management (e-CRM) and customer loyalty, and the mediating role of customer satisfaction in this relationship, among logistics service users in Malaysia. Using stimulus-organism-response (SOR) theory, e-CRM is treated as the stimulus, customer satisfaction as the organism, and customer loyalty as the response. Data were collected through an online self-administered questionnaire from 123 valid respondents in Puncak Alam, Selangor, and analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM). The results show that e-CRM is positively related to both customer satisfaction (β = 0.646) and customer loyalty (β = 0.334), and that customer satisfaction is positively related to customer loyalty (β = 0.576). Customer satisfaction was also found to partially mediate the relationship between e-CRM and customer loyalty (β = 0.372). These findings contribute to the limited body of knowledge on digital CRM practices in the logistics sector and offer logistics service providers practical direction for strengthening customer satisfaction and loyalty through e-CRM.

Keywords: *e-CRM, Customer Loyalty, Customer Satisfaction, Logistics Service Providers*

1. Introduction

Logistics service providers (LSPs) play a crucial part in the global economy, managing all transportation needs from senders through delivery to the recipients, whether domestically or internationally. The emergence of e-commerce has accelerated the demand for logistics services. The lockdowns, business closures, and numerous restrictions on the movement of humans and goods worldwide during the COVID-19 pandemic between 2020 and 2021 have further increased e-commerce transactions, which in turn increased the number of orders and deliveries (Gultekin et al., 2022; Genc and Arzaghi, 2024). The rapid expansion of global e-commerce and digital supply chains has reshaped the logistics sector, pushing Logistics Service Providers (LSPs) to shift from traditional operating models to digital-first engagement strategies. Rising demand for delivery has led to more logistics service providers entering the market. Malaysia's logistics market is anticipated to be worth roughly USD 28.88 billion in 2024 and is predicted to grow at a CAGR (compound annual growth rate) of about 5.4% throughout the period 2024-2030 (Marknteladvisors, n.d.).

The rapid rise of e-commerce, changing consumer expectations, and advancements in digital technologies have created new challenges and opportunities for logistics service providers. To effectively meet consumer needs in a competitive market, it is imperative for LSPs to provide effective services. The shift in information technology from traditional business to electronic business, coupled with an increasingly competitive business environment, globalization, knowledgeable customers, higher customer demand, and vulnerable credit risks, has compelled firms to provide the best service promptly and effectively (Venkatakrishnan et al., 2023). A customer-centric approach that engages with each consumer personally to improve customer relationship management (Mohamed et al., 2022) has driven electronic customer relationship management (e-CRM) as a vital strategy for logistics service providers aiming to meet these challenges.

With the digital transformation of industries, logistics providers are increasingly adopting e-CRM systems to improve customer relations, satisfaction, and loyalty. e-CRM is the integration of technology and customer management practices to enhance the overall customer experience (Ali & Alfayez, 2024). By effectively leveraging e-CRM, businesses can improve customer satisfaction and loyalty, which are critical for gaining a

competitive edge in today's globalized market. e-CRM's primary goal is not only to transform the marketing domain, but also to improve a company's efficiency in creating and managing customer relationships, increasing customer service, and retaining consumers in order to maximise profitability (Adlin et al., 2019). This aligns with the findings of Azila and Noor (2011), Behravan and Rahman (2012), Haghighinasab et al. (2025), and Younis et al. (2025), highlighting the role of the technology platform in fostering the establishment of effective customer interactions, hence potentially enhancing customer satisfaction and developing loyalty.

Consumer loyalty is a reflection and extension of customer satisfaction derived from utilising the services or facilities offered by a firm, leading to continued consumption. According to Kotler and Armstrong (2005), customer loyalty arises from the satisfaction of customers' expectations. Customer loyalty has emerged as a significant predictor of business success due to its essential position in the corporate landscape (Bahri-Ammari & Bilgihan, 2019; Paparoidamis et al., 2019). Companies allocate substantial effort, resources, and time to nurture customer loyalty (Izogo, 2017; Nyadzayo & Khajehzadeh, 2016; Tseng et al., 2017). Venkatakrishnan et al. (2023) indicate that there has been a tremendous change in business practices over the last 40 years, where corporations are investing extensively in technology to keep their customer base and cultivate loyalty. However, numerous organisations have struggled to secure consumer loyalty owing to inadequate strategies and resource limitations (Cheng et al., 2019; Herhausen et al., 2019; Wolter et al., 2017).

Organisations integrate e-CRM as an essential component of their business processes to foster customer loyalty (Lee-Kelley et al., 2003; Alhamdi et al., 2026), as retaining an existing client is more profitable than recruiting new consumers (Popli & Rao, 2009). Hence, organisations use diverse e-CRM methods to establish, recruit, retain, and enhance customer relationships to build customer loyalty and increase organisational profitability (Dubihlela & Khosa, 2014). Numerous studies have examined the effect of different factors on customer loyalty, including customer engagement (So et al., 2016), product quality (Kasiri et al., 2017), customer trust (Stathopoulou & Balabanis, 2016), customer satisfaction (Schirmer et al., 2018), commitment (Tabrani et al., 2018), and additional factors (Marakanon & Panjakajornsak, 2017). Considering that today's consumers possess greater knowledge and are well-informed about the various services firms, does e-CRM contribute to customer loyalty in LSP?

The role of customer satisfaction mediating the relationship between e-CRM and loyalty has garnered significant scholarly interest. Customer satisfaction significantly influences a company's economic performance (Bolton et al., 2004). When an individual is satisfied, they are likely to buy the product or service and disseminate positive word-of-mouth by referring it to friends and family members, thus fostering customer loyalty. Delivering high-quality e-services is a capability for achieving customer satisfaction, and it is only via customer satisfaction that organisations can increase loyal consumers (Taylor & Hunter, 2002). There is a lack of consensus on the role of customer satisfaction as a mediator between eCRM and customer loyalty (Kumar & Mokha, 2022).

According to the preceding discussion, this study explores the relationship between e-CRM and customers' loyalty mediated by customers' satisfaction among LSPs in Malaysia. This study contributes to the existing e-CRM literature as research on E-CRM is still lacking in developing nations (Kaur, 2016; Shastri et al., 2020) and there are limited studies on the relationship between e-CRM and customer satisfaction on customer loyalty (Alhamdi et al., 2026) in the logistics industry specifically. A good understanding of customers' demands enables logistics service providers to respond quickly to evolving customers' preferences, thereby increasing the company's revenue and competitiveness. This study helps Malaysian logistics service providers improve their services through ECRM by providing better services to increase customer satisfaction and further improve consumer loyalty, which can enhance their profitability.

2. Literature Review

Theoretical Framework

The Stimulus-Organism-Response (S-O-R) theory, developed by Mehrabian and Russell (1974), posits that external stimuli (S) influence internal processes within an organism (O), ultimately leading to behavioral responses (R) (Pandita et al., 2021). As the external environment, stimuli serve as the foundation of a sequence of an individual's psychological and behavioral reactions (Donovan & Rossiter, 1982). Organism refers to the

internal processes and psychological characteristics of the consumer, including emotions, assessments, opinions, and perceptions towards the stimulus, whereas specific responses pertain to consumer behavior, including purchase decisions, buying intention, and customer loyalty (Sautter et al., 2004; Zhang et al., 2021; Kumar & Mokha, 2022). S-O-R framework has been applied across diverse disciplines, including online shopping (Gong et al., 2023), instant messaging social software (Li et al., 2023), e-commerce (Lin & Shen, 2023; Li et al., 2024), mobile banking (Kumar & Rani, 2024), user adoption studies of mobile apps (Ashraf et al., 2021; Aslam et al., 2021; Lee & Chen, 2022), and eCRM (Mousavai et al., 2015; Kumar & Mokha, 2022). The S-O-R model has been used to investigate the relationship between E-CRM and customer satisfaction and loyalty (Mousavai et al., 2015; Kumar & Mokha, 2022). Thus, the S-O-R model is appropriate to examine the influence of E-CRM and customer satisfaction on customer loyalty.

E-CRM is viewed as a stimulus that offers various features, including personalized products and services and several payment options. It is defined as using digital technology to manage client relationships by providing efficient, engaging, and pertinent communication with clients through various electronic media (Kampani & Jhamb, 2020). Customer satisfaction is regarded as an organism that reflects the emotive and cognitive states of individuals via the observation and evaluation of stimuli. It is significant in enhancing consumer relationships and critically contributes to the success of any organization in the competitive business landscape (Kumar & Mokha, 2022). Customer loyalty is the degree to which a supplier receives exceptional returns for the efforts it makes in working with its customers. As behavioral responses emerge upon exposure to stimuli, the formation of the consumer's internal processes occurs. As customer loyalty fosters positive word-of-mouth and the intention to engage with E-CRM services, it is regarded as a response (Kumar & Mokha, 2022; Gam et al., 2025).

With the advancement of information and communication technology, businesses are transitioning from traditional customer relationship management (CRM) to electronic customer relationship management (e-CRM) in an effort to improve service levels and customer experience through digital means amid intense market competition (Kampani & Jhamb, 2020). The effective application of e-CRM not only enhances customer satisfaction (CS) but also promotes the formation of customer loyalty (CL) (Kamal et al, 2021). Furthermore, empirical studies across different industries (such as banking, insurance, elderly care, port logistics, etc.) support this viewpoint, providing theoretical foundations and practical guidance for businesses on how to build long-term customer relationships.

e-CRM and Customer Satisfaction

e-CRM excels at utilizing digital tools (such as personalized marketing, automated customer service, data analysis, and prediction) to integrate customer information, improve service response speed and information delivery quality, thereby enhancing customer satisfaction (Kamal et al, 2021; Srivastava & Rai, 2013). Prior studies showed that e-CRM and customer satisfaction are interrelated (Abdulfattah, 2012; Al-Dmour et al., 2019; Kumar & Mokha, 2022; Srivastava & Rai, 2013). e-CRM effectively enhances customer relationships through the establishment of a virtual environment that can increase customer satisfaction (Kumar & Mokha, 2022). Efficient e-CRM systems reduce response times for customer inquiries and complaint handling and meet diverse customer needs through personalized financial product recommendations in the banking sector (Abdulfattah, 2012; Aldaihani et al., 2018), thus enhancing satisfaction across various customer segments. Studies found that e-CRM can significantly improve customer experience and further increase customer satisfaction in the hotel and insurance sectors (Rafiki et al., 2024; Nikou et al., 2016). The hypothesis is developed as follows:

H1: e-CRM is positively related to customer satisfaction

The Relationship Between Customer Satisfaction and Customer Loyalty

Numerous studies indicate that customer satisfaction is an important condition that leads to customer loyalty (Sheng & Liu, 2010; Kawa & Pisz, 2023; Banerji & Singh,2024). Satisfied customers are seemingly to be loyal towards a product or service (Ababneh et al., 2022) and intend to make repeat purchases, promote related products or services, and recommend the brand to those around them, forming a high level of customer loyalty (Krishna Burra et al., 2022; Zahro & Miranti, 2024). This suggests that customer satisfaction and customer loyalty are directly related. However, there are special factors such as market competition, price sensitivity, and the attractiveness of substitutes that can impact this relationship, making satisfaction alone potentially

insufficient to guarantee customer loyalty, thus possibly weakening the conversion effect of satisfaction on loyalty (Srivastava & Rai, 2013; Sleimi et al., 2020). The following hypothesis is developed:
H2: Customer satisfaction is positively related to customer loyalty.

The Relationship Between e-CRM and Customer Loyalty

e-CRM not only plays a positive role in enhancing customer satisfaction but also directly promotes the formation of customer loyalty (Dehghanpouri et al, 2020; Amalyah et al., 2025). The application of digital platforms in enterprises helps businesses achieve real-time interaction with customers, providing higher-quality personalized services that further strengthen customer dependence on and identification with the brand, thus enhancing customer loyalty (Kamal et al, 2021; Mang'unyi et al., 2018; Karphammar & Brettschneider, 2021; Venkatakrishnan et al., 2023). Banks adopting E-CRM experience significantly reduced customer churn rates (Kumar & Mokha, 2020). In the telecommunications industry, the application of E-CRM has promoted improved marketing performance of relevant companies, thereby fostering further development of the telecommunications industry (Khaligh et al., 2012; Sunny & Abolaji, 2016; Emaluta et al., 2019). Past studies revealed a positive relationship between e-CRM and customer loyalty in various sectors such as the hotel industry, banking industry, e-commerce, etc. (Haghighinasab et al., 2025; Huda et al., 2021; Kariman et al., 2022; Khan & Khawaja, 2013; Kumar & Mokha, 2022; Mousavai et al., 2015; Mulyono and Situmorang, 2018; Sasono et al., 2021; Shastri et al., 2020; Younis et al., 2024). The hypothesis is developed as follows:
H3: e-CRM is positively related to customer loyalty.

e-CRM, Customer Satisfaction and Customer Loyalty

The S-O-R model is applied by positing that e-CRM serves as an agent stimulating people's emotive and cognitive states, which will lead to specific reactions of customer loyalty. In this manner, customer satisfaction mediates the role of e-CRM in enhancing customer loyalty. Appropriate e-CRM performance improves business-customer interaction and fosters the evolution of a virtual environment, which increases customer satisfaction (Upadhyaya, 2020). Customers who are satisfied with the products or services offered instill a positive attitude and a sense of fulfilment, resulting in customer loyalty (Hayati et al., 2020; Li et al., 2021). The significant role of customer satisfaction in mediating the relationship between E-CRM and customer loyalty has been found (Haghighinasab et al., 2025; Khan & Khawaja, 2013; Kumar & Mokha, 2022; Mulyono & Situmorang, 2018; Kariman et al., 2022). Thus, the hypothesis is as follows:
H4: Customer satisfaction mediates the relationship between e-CRM and customer loyalty.

3. Methodology

This study applies a purposive convenience sampling method by collecting data using a self-administered questionnaire through the Google Forms online platform among residents in Puncak Alam, Selangor, in 2025. Target respondents are those who have used logistics services. Prior to completing the questionnaire, respondents were informed of the purpose of the study and participated voluntarily; informed consent was obtained from all respondents. Given the minimal risk involved, formal ethics committee approval was not sought. A total of 139 questionnaires were collected, with 123 questionnaires (88.5%) being valid. The sample size fulfilled the minimum required sample size (N = 107) using the G*Power statistical power analysis tool (Faul et al., 2007) with the power of 0.95 and a medium effect size of 0.15. Table 1 presents the demographic characteristics of the respondents.

Table 1: Demographic Characteristics Analysis

Variables	Frequency (N=123)	Percent
Gender		
Female	77	62.6%
Male	46	37.4%
Age		
Below 20 years old	4	3.3%
20 – 29 years old	80	65.0%
30 – 39 years old	30	24.4%
40 – 49 years old	5	4.1%

50 – 59 years old	1	0.8%
60 years old and above	3	2.4%
Household Monthly Income		
Less than RM3000	53	43.1%
More than RM10000	9	7.3%
RM3001 – RM5000	38	30.9%
RM5001 – RM10000	23	18.7%
Education		
Primary Education	2	1.6%
Secondary education	14	11.5%
Tertiary education	75	61.5%
Postgraduate education	31	25.4%
Occupation		
Executive level	41	33.3%
Non-Executive level	54	43.9%
Student	26	21.1%
Housewife	2	1.6%

Note. n = 122 for Education; one respondent did not report educational level.

All three constructs and measurement items were adopted from Kamal et al. (2021). There were seven, six, and four items for e-CRM, customer satisfaction, and customer loyalty, respectively. A 5-point Likert scale was used to measure all items, which ranged from 1 = strongly disagree to 5 = strongly agree.

As data collection was done on a single-source basis, it is necessary to examine common method variance as suggested by Podsakoff et al. (2003). The marker variable method was assessed by adopting the marker variable measurement scale of attitude toward the color blue developed by Miller and Simmering (2023). Table 2 shows that the changes in R2 values between the models with and without marker variables are less than 10%; thus, common method bias is not a serious problem.

Table 2: Comparison of R^2 Value Between The Model Without and With The Marker Variable

Relationship	Without marker variable	With marker variable
Customer satisfaction	0.418	0.440
Customer loyalty	0.692	0.694

This study used partial least squares structural equation modelling (PLS-SEM) to analyze the data using the SmartPLS 4.0 software (Ringle et al., 2024). PLS-SEM analysis incorporates the measurement model and structural model. The measurement model assesses the validity and reliability of the outer model and structurally tests the hypotheses developed in the study.

4. Results

Measurement Model

The convergent validity and the discriminant validity were examined in the measurement model (Hair et al., 2022). Convergent validity includes factor loadings, average variance extracted (AVE), and composite reliability (CR), which are shown in Table 3. The results indicate that convergent validity was generally acceptable. Although the loadings for ECRM4 (0.621) and ECRM5 (0.649) fell below the conventional 0.70 threshold, they were retained as the AVE and CR for e-CRM remained above the recommended thresholds of 0.5 and 0.7, respectively. The AVEs for all constructs were above 0.5, and all CRs were above 0.7.

Table 3: Measurement Model

Construct	Items	Loadings	CR	AVE
Customer Loyalty (CL)	CL1	0.943	0.941	0.841
	CL2	0.901		
	CL3	0.907		
Customer satisfaction (CS)	CS2	0.825	0.909	0.714
	CS3	0.864		
	CS4	0.831		
	CS5	0.858		
e-Customer Relationship Management (e-CRM)	ECRM1	0.707	0.872	0.535
	ECRM2	0.83		
	ECRM3	0.844		
	ECRM4	0.621		
	ECRM5	0.649		
	ECRM6	0.706		

Note: Four low-factor-loading items (e.g., ECRM7, CS1, CS6, and CL4) were deleted.

Further, discriminant validity with the multitrait-multimethod matrix was evaluated with the heterotrait-monotrait (HTMT) ratio of correlations as recommended by Henseler et al. (2015) and is shown in Table 4. All HTMT values were below the threshold level of HTMT90 (Gold et al., 2001), supporting discriminant validity, although the HTMT value between customer satisfaction and customer loyalty (0.893) approached this threshold, reflecting the conceptual closeness between the two constructs in the logistics service context.

Table 4: **HTMT Ratio**

	CL	CS	E-CRM
CL			
CS	0.893		
e-CRM	0.812	0.767	

Structural Model

Structural model assessment to test the hypotheses relationship with a bootstrapping procedure of 10,000 resamples that includes standard beta, t-values, confidence intervals, and the effect sizes (f2) (Hair et al., 2022).

The analysis results in Table 5 indicate that e-Customer Relationship Management ($\beta = 0.646$, $p < 0.001$) is positively related to Customer Satisfaction, indicating H1 was supported. The R^2 value of 0.418 indicates that 41.8% of the variation in Customer Satisfaction is explained by the variation of e-Customer Relationship Management. Customer Satisfaction and e-Customer Relationship Management both have a positive relationship with Customer Loyalty. Thus, H2 and H3 were supported. The R^2 value of 0.692 indicates that 69.2% of the variation in Customer Loyalty is explained by Customer Satisfaction and e-Customer Relationship Management. The strength of the relationship between two variables is evaluated by the effect size. Following guidelines by Cohen (1992), f^2 values of 0.02, 0.15, and 0.35 indicate small, medium, and large effects, respectively. As shown in Table 5, the effect size of E-CRM ($f^2 = 0.718$) on CS was high. The effect size of CS on CL was large, and the effect size of E-CRM on CL was moderate.

The mediation hypothesis testing, as suggested by Preacher and Hayes (2004; 2008), was assessed by bootstrapping the indirect effect to test the mediation hypothesis, and the results are shown in Table 6. Hypothesis H4 of e-CRM -> CS -> CL ($\beta = 0.372$, $p < 0.001$) was supported. Thus, the mediation effect of customer satisfaction is significant, as the confidence interval bias-corrected 95% did not contain 0.

Table 5: Hypothesis Testing Direct Effects

Hypothesis	Relationship	Std Beta	Std Error	t-values	p-values	BCI LL	BCI UL	f^2	VIF
H1	e-CRM -> CS	0.646	0.061	10.656	P<0.001	0.528	0.732	0.718	1.000
H2	CS -> CL	0.576	0.094	6.158	p<0.001	0.419	0.724	0.628	1.718
H3	e-CRM -> CL	0.334	0.102	3.272	0.001	0.168	0.501	0.211	1.718

Table 6: Hypothesis Testing Indirect Effects

Hypothesis	Relationship	Std Beta	Std Error	t-values	p-values	BCI LL	BCI UL
H4	e-CRM -> CS -> CL	0.372	0.08	4.649	P<0.001	0.251	0.506

Predictive relevance of the model is assessed with PLS-Predict as recommended by Shmueli et al. (2019). With a 10-fold procedure of the PLS-Predict test, the results of PLS-Predict are shown in Table 7. As all items of the PLS-SEM RMSE values of the dependent variables were lower than the LM RMSE, this indicates the model has strong predictive power.

Table 7: PLS-Predict

	PLS-SEM		LM	PLS - LM
	Q^2predict	RMSE		RMSE
CL1	0.49	0.604	0.628	-0.024
CL2	0.337	0.675	0.701	-0.026
CL3	0.389	0.589	0.596	-0.007
CS2	0.303	0.698	0.73	-0.032
CS3	0.295	0.779	0.824	-0.045
CS4	0.246	0.727	0.753	-0.026
CS5	0.265	0.724	0.754	-0.030

5. Conclusion and Recommendations

The study examines the relationship between e-CRM and customer loyalty in the logistics industry, with customer satisfaction as a mediator. The analysis results indicate that e-CRM was positively related to customer satisfaction, consistent with previous studies (Abdulfattah, 2012; Al-Dmour et al., 2019; Anjarwati et al., 2026; Khan & Khawaja, 2013; Kumar & Mokha, 2022; Upadhyaya, 2020). Customers who are satisfied with the services provided tend to have a stronger relationship with service providers (Anjarwati et al., 2026), facilitated by better communication and engagement with customers through various technologies and digital channels such as email, web, and social media. Thus, e-CRM not only contributes to the establishment of virtual environments but also strengthens long-term customer relationships, which is associated with higher customer satisfaction (Kumar & Mokha, 2022). The results also show that customer satisfaction was positively related to customer loyalty, consistent with past studies (Ababneh et al., 2022; Hayati et al., 2020; Tahir, 2020). Customer satisfaction with the services offered by logistics service providers is associated with an increase in their loyalty towards the service provider, which may lead them to be more inclined to choose and recommend a particular logistics service provider to their friends and relatives (Kumar & Mokha, 2022).

Findings also show that e-CRM was positively related to customer loyalty, consistent with past findings (Khan & Khawaja, 2013; Kumar & Mokha, 2022; Mousavai et al., 2015; Mulyono & Situmorang, 2018; Shastri et al., 2020; Haghighinasab et al., 2024). As e-CRM helps businesses provide better customer service by managing online customer support inquiries, resolving issues efficiently, and providing timely assistance, customers are more likely to remain loyal to their logistics service provider.

The results support customer satisfaction in mediating the relationship between e-CRM and customer loyalty (Haghighinasab et al., 2025; Khan & Khawaja, 2013; Kumar & Mokha, 2022; Mulyono & Situmorang, 2018; Syaifullah et al., 2024). e-CRM is essential in enhancing customer satisfaction and retention as it effectively facilitates communication, personalizes interactions, and optimizes service delivery (Ali & Alfayez, 2024), which is associated with greater customer loyalty. e-CRM uses digital platforms to manage customer interactions through online customer support and social media engagement. Effectively managing online customer support inquiries, resolving issues efficiently, providing timely assistance, and responding to feedback may be associated with higher customer satisfaction and, in turn, greater customer loyalty.

Based on the findings, logistics service providers are encouraged to invest in e-CRM practices that support consistent, responsive, and personalized communication with customers, as these practices were associated with both customer satisfaction and customer loyalty in this study. Practical steps may include maintaining active digital channels for customer service, ensuring prompt responses to customer inquiries, and using customer data to tailor communication to individual needs.

Because customer satisfaction was found to partially transmit the relationship between e-CRM and customer loyalty, logistics service providers should treat customer satisfaction as an ongoing outcome to be monitored, rather than assuming that digital tools alone will secure customer loyalty. Regular collection of customer feedback and timely resolution of service issues may help sustain the satisfaction levels needed to support loyalty.

Firms in the logistics sector may also consider using e-CRM as a basis for differentiating their services from competitors, given that customers in this study reported forming loyalty based on their general experience with digital customer engagement rather than any single service feature. Continued investment in digital customer relationship capabilities may therefore support customer retention and long-term business performance.

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The Relationship Between Supply Chain Integration, Green Supply Chain Management Practices and Sustainability Performance: A Conceptual Framework

Norzawani Ibrahim[1], *Nur Najjah Abd Rahim[1], Norasekin Abd Rashid[1], Mior Faizmie Yusof Za Ba[2], Nur Amalina Abd Rahim[3]
[1]Faculty of Business and Management, Universiti Teknologi MARA Puncak Alam, Malaysia
[2]Faculty of Business Management & Professional Studies, Management & Science University (MSU), Shah Alam, Selangor, Malaysia
[3]Associate Chartered Banker, Asian Institute of Chartered Bankers, Malaysia
Email: nzawani@uitm.edu.my, *najjahabdrahim@uitm.edu.my, norasekinrashid@uitm.edu.my, mior_faizmie@msu.edu.my, nuramalina.abdrahim@gmail.com
Corresponding Author: Nur Najjah Abd Rahim

Abstract: A survey conducted by the SME Association among 1,713 SME members revealed that 20% of the respondents were considering permanently closing their business in the next six months due to this issue. In addition, the growth of SMEs in 2021 registered at -5.6% which was lower than Malaysia's GDP in 2015. Taking note of these issues, this study is going to develop the framework for Malaysian SMEs by investigating the relationship between supply chain integration, green supply chain management (GSCM) practices and sustainability performance. Resource-based view (RBV) theory, and natural resource-based view (NRBV) theory are integrated to enlighten the probable relationship between the variables to develop a research framework. A total of 576 SME companies in Malaysia will participate in this study. The data will be collected via the survey method. Partial Least Squares (PLS) procedure will be applied to analyze the data and test the hypotheses of this study. The significance of this study will contribute to the body of knowledge and practice by providing a strong research framework for a clear understanding that describes the effect of implementing supply chain integration among SME companies and the role of GSCM practices towards sustainability performance that would be utilized by the companies and the academicians.

Keywords: *Small and Medium Enterprise, Supply Chain Integration, Green Supply Chain Management Practices, Sustainability Performance*

1. Introduction and Background

Small and Medium Enterprises are important contributors to national income, global economic development, as well as job creation. There have been several studies about the significance of SMEs to the global economy. SMEs also contribute to higher export rates, which is highly significant for business development. Due to that, many countries are aware of the need to support SMEs through various programs and policies in order to improve SME performance. Regarding total employment and GDP contribution for low-income countries, SMEs have contributed almost 60% and 70%, respectively. SMEs also contributed over 70% to GDP and 95% to total employment for middle-income countries. For high income countries, SMEs provided to over 65% of total employment and 55% of GDP for high income countries (Ramdan et al., 2022). However, two years after COVID-19 was announced as a global pandemic, the post-pandemic period has severely affected global SME performance. Particularly in Malaysia, a survey conducted by the SME Association among 1,713 SME members revealed that 20% of the respondents were considering permanently closing their business in the next six months due to this issue. In addition, the growth of SMEs in 2021 registered at -5.6% which was lower than Malaysia's GDP in 2015. In addition, considering global environmental performance, SMEs are also responsible for major carbon emissions (Shashi & Cerchione, 2018). SMEs are accountable for almost 70% of worldwide industrial pollution, necessitating immediate action to implement potential environmental prevention. Accordingly, SMEs should not only concentrate on financial performance, but also on environmental performance across their supply chain. Understanding the importance of SMEs to the Malaysian economy and the issue of post Covid and environmental issues, effective ways to quickly solve the issue are by having supply chain integration and implementing green supply chain management practices. This sector requires strong supply chain integration to ensure that SMEs strategically collaborate with their supply chain partners and collaboratively manages intra-organization and inter-organizational linkages within a company and with upstream and downstream supply chain partners. The aim is to achieve efficiencies in terms of product and service processes, share necessary information, provide high value to the customer and improve performance.

Green supply chain management practices can also be an effective strategy for SMEs to achieve sustainability performance since this practice can reduce pollution, waste and emissions.

Although supply chain integration research has been conducted in many countries such as India (Shashi & Cerchione, 2018), China (Flynn et al., 2010), the United Kingdom (Vanpoucke et al., 2014), and the United States (Kannan & Tan, 2010), there are still limited studies on supply chain integration in Malaysian SMEs. In addition, based on available literature, several studies have conducted a systematic literature review analysis to explain supply chain integration, such as (Fabbe-Costes & Jahre, 2008; Ataseven & Nair, 2017). Although much research has been done on supply chain integration, there is still limited research conducted on the effect of supply chain integration on sustainability performance specifically in the Malaysian SMEs context. On the other hand, previous studies such as Zhu et al. (2017), Razak and Ibrahim (2020), Ibrahim et al. (2021), Eltayeb et al. (2011), Green et al. (2012), and Tan et al. (2016) in their quantitative studies have investigated the implementation of green supply chain management practices and their effect on improving economic performance and environmental performance. However, there is still less research focus on GSCM practices as a strategy towards sustainability performance. Thus, this study attempts to fill up this existing gap by examining the GSCM practices among SMEs in Malaysia to achieve sustainability performance in terms of economic, environmental and social performance.

The resource- based view (RBV) and natural resource-based view (NRBV) theories are utilized as a guiding principle to investigate and explain the relationship between supply chain integration, GSCM practices, and sustainability performance among Malaysian SMEs. According to RBV organizations are a collection of resources, some of which might be called strategic (Wernerfelt, 1984). Thus, corporations seeking a competitive edge must combine resources uniquely and distinctly from other organizations that may not be able to do so (Dyer and Singh, 1998). At the same time, they must be concerned with the disparate allocation of resources among organizations engaged in the supply chain integration process (Barney, 1991). As a result, the incentives for supply chain integration are focused on acquiring limited and specialized resources to secure and retain a competitive edge. Extended from resource-based view (RBV) theory, Hart (1995) introduced NRBV by introducing the natural environment into RBV's drivers as a competence for the firm to gain a competitive advantage which leads this study to focus on the role of the strategy of GSCM practices. Accordingly, the purpose of the present study is to investigate the effect of supply chain integration on sustainability performance. A previous study by Kumar et al. (2017) examined four dimensions of supply chain integration namely supplier integration, internal integration, customer integration, and information integration in improving performance. While employing the studies conducted by Kumar et al. (2017) and Delic et al. (2019), at the same time, this study integrates GSCM practices as a mediating role in this relationship. The originality of this study lies in its investigation of GSCM practices as the mediator while this study responds to the demand by Kumar et al. (2017) and Delic et al. (2019) for further research to introduce the role of GSCM practices as a strategy specifically as a mediating role in the conceptual framework.

2. Literature Review

Supply Chain Integration

The increasing degree of rivalry among organizations internationally has resulted in a change to do more than simply strategy design and implementation, but also to seek partnerships with other firms that would lead to a competitive edge in the marketplace (Huang et al., 2014). Manufacturing companies have spent years focusing on building strategies that will bring about the appropriate amount of transformation and operational effectiveness. Firms have understood, however, that developing strategies and integrating internal operations, suppliers, and consumers in a commercial relationship is the best way to get a competitive edge (Frohlich and Westbrook, 2001). This provided the foundation for supply chain integration (SCI) as a method used by companies seeking to improve their performance by fostering stronger linkages among supply chain links (Smart, 2008). Organizations shifted from their earlier vertical integration tactics to become an association of enterprises that collaborate to acquire, manufacture, and sell products and services to their consumers. SCI is focused on the synergy that occurs between a firm's internal processes and external activities within its supply chain, which leads to organizational performance (Chen et al., 2009).

The dimension of supply chain integration

Supplier integration denotes a situation in which suppliers are integrated into the firm's essential decision-making processes, with information about demand predictions, production, and inventory levels shared between them. It entails focus businesses collaborating with their major suppliers to optimize the advantages of the relationship, such as increasing lead times, innovation, and quality (Thun, 2010). The customer-supplier integration process should focus on strengthening connections between both parties for their mutual benefit (Furlan et al., 2006). The primary motivation for supplier integration with customers should be to improve the customer experience or to better serve them.

Customer integration in the supply chain allows enterprises to have a deeper understanding of the requirements and special demands of their customers, allowing them to serve them better. Integrating customers into a supply chain focuses on gathering information from consumers such as their purchasing habits, product preferences, and ability to acquire items, which is then utilized to make better decisions throughout the production process or sales to customers (Lotfi et al., 2013). When businesses interact with their consumers, they are able to respond quickly and efficiently to their customers, boosting order fulfilment and visibility.

For companies aiming to connect with their consumers and suppliers, **information integration** is essential (Amue et al., 2014). However, information integration is not limited to technological efficiency and applicability. It necessitates the inputs and role-playing of people, as well as technical systems, to generate, sort, process, and disseminate information to the appropriate location at the appropriate time for effective decision-making (Sadler, 2008). Data may be collected in real time when information is exchanged across the supply chain, as better communications with other supply chain members are established, leading to enhanced customer service and demand forecasts (Amue et al., 2014).

Green supply chain management (GSCM) practices

People began to consider the notion of environmental quality in the 1990s. Beamon (1999) changed the traditional supply chain into a green supply chain to decrease waste and pollution while minimizing resource utilisation. The green supply chain was created by including recycling, remanufacturing, and reusing operations into the standard supply chain design. In the 2000s, academics were interested in the green supply chain idea and sought to understand how to implement it in a practical manner. As a result, academics began to investigate ways to manage the green supply chain and promote the notion of green supply chain management to worldwide practice (Zhu et al., 2019; Baojuan, 2008; Srivastava, 2007; Zhu & Sarkis, 2004; Kogg, 2003; Zsidisin & Siferd, 2001). Green supply chain management, according to Hajikhani et al. (2012) and Baojuan (2008), includes activities such as green designing, green production, green packaging, green marketing, and green recycling. Consumers nowadays want items that solve the problem of trash disposal (Dowie, 1994). Green supply chain management literature has expanded to include green supply chain management methods. Green supply chain management, according to Diabat and Govindan (2011), is currently regarded as a green approach that is consistent in sustaining environmental performance at all management levels and across the supply chain. The 'green practice,' according to Groznik and Erjavec (2012), is linked to the green economy, and it attempts to improve three primary things: enhancing social fairness, lowering environmental risk, and improving the ecological problem. According to Field and Sroufe (2007), the business management team is identifying green supply chain management methods to satisfy the rising demand for environmentally friendly products to enhance environmental performance and save costs.

Sustainability performance

There is no clear and agreed-upon definition of sustainability performance since it is frequently limited to environmental consequences rather than social performance (Henri and Journeault, 2010). The performance of a corporation in terms of economic, environmental, and social issues is referred to as sustainability performance. Various approaches are used to examine and monitor the effects of these factors. Much of the research on business sustainability performance has concentrated on links, such as those between environmental, social, and economic performance (Artiach et al., 2010). According to Baumgartner (2008), a systemic corporate sustainability performance evaluation that demonstrates the interconnections between the system (business, society, and environment) is necessary to determine if corporate operations have a positive impact and contribute to SD principles.

3. Proposed Conceptual Framework

The proposed research framework examines the relationships among Supply Chain Integration (SCI), Green Supply Chain Management (GSCM) practices, and Sustainability Performance (SP). The framework is underpinned by the Resource-Based View (RBV) and Natural Resource-Based View (NRBV), which posit that firms achieve superior sustainability outcomes by developing valuable, rare, and inimitable capabilities, particularly those related to organizational integration and environmental management (Barney, 1991; Hart, 1995).

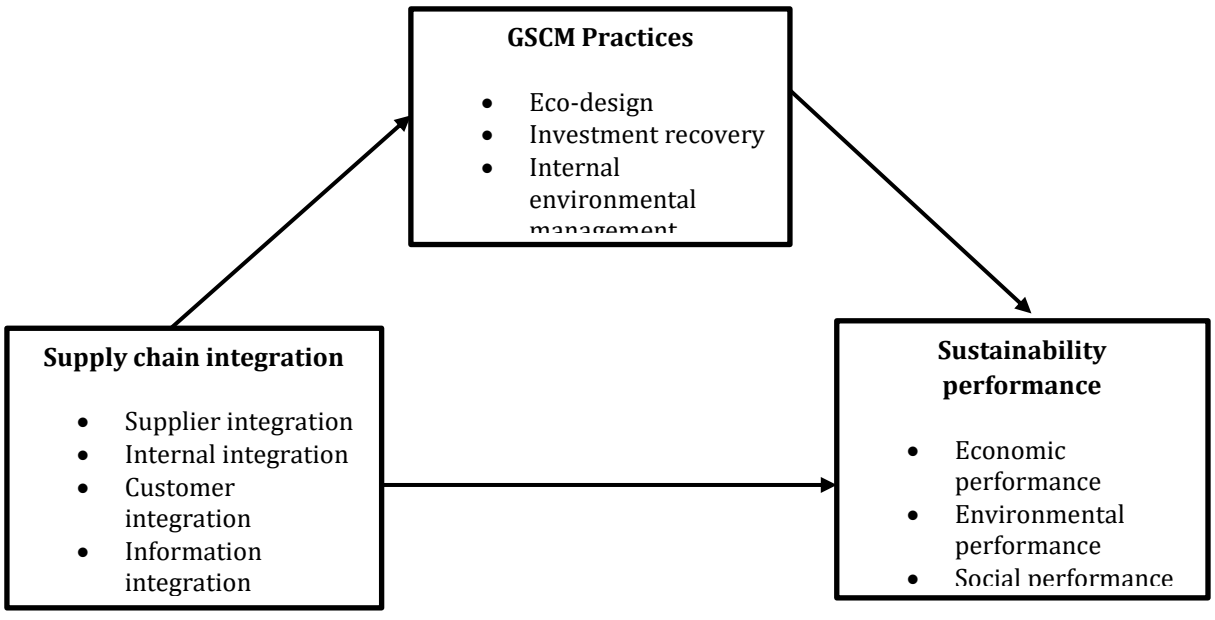
In this framework, Supply Chain Integration (SCI) is conceptualized as the independent variable and represents a multidimensional capability encompassing supplier integration, internal integration, customer integration, and information integration. These dimensions collectively reflect the extent to which a firm coordinates processes, aligns objectives, and shares information across functional units and supply chain partners. SCI is therefore considered a strategic capability that enhances operational efficiency, responsiveness, and inter-organizational coordination in dynamic supply chain environments.

The framework further positions Green Supply Chain Management (GSCM) practices as a mediating construct. GSCM refers to the integration of environmental considerations into supply chain activities, including internal environmental management, eco-design, and investment recovery. SCI is expected to facilitate the adoption and effective implementation of GSCM practices by improving communication flows, strengthening relational trust, and enhancing cross-functional and inter-organizational coordination. As a result, firms with higher levels of SCI are better positioned to embed environmental sustainability into their operational and strategic decision-making processes.

Finally, Sustainability Performance (SP) is specified as the dependent variable, operationalized through the Triple Bottom Line (TBL) framework, which encompasses economic, environmental, and social performance dimensions. The framework proposes that SCI contributes both directly and indirectly to sustainability performance. The direct relationship reflects the efficiency and coordination benefits of integration, while the indirect relationship operates through GSCM practices, which translate integrated supply chain capabilities into environmentally responsible actions and improved sustainability outcomes.

Overall, the model proposes a mediation-based relationship, whereby SCI enhances GSCM practices, which subsequently improve sustainability performance. This reflects the view that sustainability is achieved not merely through isolated operational improvements but through the synergistic integration of supply chain capabilities and environmental management practices.

Figure 1: Proposed Conceptual Framework of the Study



4. Proposed Research Methodology

This research will be conducted as a correlational study in determining relationships among variables with minimal researcher involvement in the natural environment (Sekaran & Bougie, 2013). The correlational study is an ideal option for this research since the objective is to investigate the relationship between supply chain integration, GSCM practices and sustainability performance among Malaysian SMEs. Simultaneously, literature reviews will be utilized to analyze the dimensions of supply chain integration. The correlational study is also cross-sectional where the data are collected and measured at a single point in time (Zikmund, 2003). This study uses a survey method because it is the most appropriate research design to achieve the objective of this study.

The sampling frame for this study is the Small and Medium Enterprise companies in Malaysia. The list of the population is obtained from SME Corp Malaysia (2022). According to SME Corp (2022) the number of populations of this study or SME companies in Malaysia is 1,226,494. For this study, the researcher used the Raosoft Calculator as a guideline to determine the random sample size from the determined population. Based on the Raosoft Calculator, the minimum sample size suggested for 1,226,494 is 385 SMEs, which also seemed to fit well with the requirement of sample size for SEM. Since this study will use SEM-PLS as a tool for data analysis, a cautious decision was made in determining the appropriate sample size for this study. Hair et al. (1998) recommended that the sample should be at least 100 observations to obtain reliable results.

For this study, a simple random sampling technique will be used, as it enables generalization to the study population (Creswell, 2014). Hair et al. (2010) have also highlighted that the simple random sampling technique could prevent bias in choosing respondents because all elements in the population have an equal chance of being selected as respondents.

Instrument

All items in the questionnaire will be adapted from previous studies and measured using a five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The measurement instruments for this study are presented in Table 1, Table 2, and Table 3, as follows:

Table 1: Instrumentation of Supply Chain Integration

Construct	Number of Items	Key Focus	Source
Supplier Integration	6 items	The degree of collaboration, coordination, and information sharing with key suppliers.	Flynn et al. (2010); Zhao et al. (2011)
Internal Integration	6 items	Coordination and collaboration across functional departments within the firm.	Flynn et al. (2010); Basnet (2013)
Customer Integration	6 items	Collaboration and information sharing with key customers.	Flynn et al. (2010); Zhao et al. (2011)
Information Integration	6 items	The use of systems and real-time data sharing across the supply chain.	Zhao et al. (2011); Flynn et al. (2010); Neubert et al. (2018)
Total	**24 items**	**Supply Chain Integration**	

Table 2: Instrumentation of Green Supply Chain Management Practices

Construct	Number of Items	Key Focus	Source
Eco-Design	6 items	Green product development & design	Zhu et al. (2008, 2012); Sarkis (2012)
Investment Recovery	6 items	Waste reuse, recycling, asset recovery	Zhu et al. (2008, 2012); Srivastava (2007)
Internal Environmental	7 items	Environmental policies, management commitment	Zhu et al. (2008, 2012); Chan et al. (2012);

Construct	Number of Items	Key Focus	Source
Management			Green et al. (2012)
Total	**19 items**	**GSCM practices**	

Table 3: Instrumentation of Sustainability Performance

Construct	Number of Items	Key Focus	Source
Economic Performance	6	Profitability, cost, competitiveness	Zhu et al. (2008, 2012)
Environmental Performance	6	Pollution, energy, resources	Zhu et al. (2008, 2012); Sarkis (2012)
Social Performance	6	CSR, employees, stakeholders	Green et al. (2012)
Total	**18**	**Sustainability Performance**	

Data Analysis

The data will be coded and analyzed using SPSS Version 28 for preliminary screening and descriptive statistics. Data will be checked for missing values, outliers, and inconsistencies before analysis. Descriptive statistics, including frequency, percentage, mean, and standard deviation, will be used to summarize respondents' profiles and variable distributions. Hypotheses will be tested using Partial Least Squares Structural Equation Modelling (PLS-SEM) via SmartPLS. This method is appropriate due to its suitability for complex predictive models and minimal distributional assumptions. It allows simultaneous assessment of both measurement and structural models. The measurement model will be evaluated for internal consistency reliability (Cronbach's alpha, Composite Reliability), convergent validity (AVE), and discriminant validity (Fornell–Larcker criterion and HTMT ratio). The structural model will be assessed using bootstrapping to determine path significance, while R^2, f^2 and Q^2 will be used to evaluate explanatory power, effect size and predictive relevance.

5. Managerial Implications and Recommendations

This study contributes to the growing body of knowledge on sustainable supply chain management by integrating Supply Chain Integration (SCI) and Green Supply Chain Management (GSCM) practices in explaining sustainability performance. Recent studies confirm that GSCM practices significantly enhance economic, environmental, and social performance, particularly when supported by strong inter-firm integration and coordination mechanisms (Kamra et al., 2024; Green et al., 2012). Accordingly, the study extends the Resource-Based View (RBV) and Natural Resource-Based View (NRBV) by positioning SCI as a strategic capability that facilitates the effective implementation of green practices to achieve superior sustainability outcomes.

From a managerial perspective, the findings suggest that firms should not treat sustainability initiatives as isolated environmental actions but rather embed them within integrated supply chain systems. Strengthening internal integration and collaboration with suppliers and customers enhances information sharing, joint decision-making, and process alignment, which in turn improves the effectiveness of eco-design, internal environmental management, and other GSCM practices. This integrated approach leads to improved resource efficiency, reduced environmental impact, and enhanced competitiveness (Zhu et al., 2008; Sarkis, 2012; Green et al., 2012).

In terms of practical recommendations, managers are encouraged to invest in digital systems that support real-time information sharing across supply chain partners, as well as to develop long-term strategic partnerships with key suppliers and customers to support joint sustainability initiatives. Policymakers should further promote sustainability by providing incentives for green innovation, strengthening environmental regulations, and supporting supply chain collaboration platforms, particularly for SMEs in developing economies. Institutional and stakeholder pressures can also help accelerate GSCM adoption and improve sustainability

outcomes (Zhu et al., 2013).

This study develops a conceptual framework examining the relationships between Supply Chain Integration (SCI), Green Supply Chain Management (GSCM) practices, and Sustainability Performance (SP). Drawing on the Resource-Based View (RBV) and Natural Resource-Based View (NRBV), the framework positions SCI as a strategic organizational capability that enhances coordination, collaboration, and information sharing across internal functions and external supply chain partners.

Conclusion

The study further conceptualizes GSCM practices, including internal environmental management, eco-design, and investment recovery as a mediating mechanism through which SCI translates into improved sustainability outcomes. From a triple bottom line perspective, sustainability performance is defined through economic, environmental, and social dimensions, reflecting a holistic assessment of organizational outcomes.

The proposed framework suggests that sustainability performance is not achieved through fragmented environmental initiatives but through integrating supply chain capabilities with structured green practices. SCI plays a foundational role in enabling the effective implementation of GSCM practices, which in turn enhance overall sustainability performance. This study contributes to the literature by integrating operational and environmental perspectives within a unified model of sustainability in supply chains. It provides a basis for future empirical validation and encourages further examination of the mechanisms through which supply chain integration enhances environmental and organizational performance outcomes in complex and dynamic business environments.

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Modeling The Qualitative Sub-Domains of Sleep Health: A Theoretical Framework for Student Health-Related Quality of Life

*Liatul Izian Binti Ali Husin, Dilla Syadia Ab Latiff, Noorizan Mohamad Mozie, Norfazlina Ghazali
Universiti Teknologi MARA, Malaysia
Email: *liatul@uitm.edu.my, dillasyadia@uitm.edu.my, noorizan0321@uitm.edu.my, norfazlina4843@uitm.edu.my
Corresponding Author: Liatul Izian Binti Ali Husin

Abstract: This paper establishes an integrative theoretical model examining the direct mechanisms connecting sleep latency and structural sleep disturbances (both somatic and micro-environmental) to university students' Health-Related Quality of Life (HRQoL). By moving beyond traditional, unidimensional volumetric sleep metrics (such as total sleep duration), this framework bridges Sleep Hygiene Theory and the Cognitive-Behavioral Model of Insomnia to capture qualitative sleep architecture. This study aims to integrate established methods of sleep assessment (Pittsburgh Sleep Quality Index [PSQI] and health indices EuroQol [EQ-5D]) and to develop a framework of new qualitative and quantitative methods to assess the negative impact of poor sleep on the functioning and productivity of individuals. To achieve the framework's immediate relevance, functional tactical innovations were modelled based on a thorough analysis of the latest literature in the field of behavioural medicine and public health for the years 2024-2026. The main goal of the last conceptual model is to provide immediate, data-supported, and feasible recommendations to inform wellness-related policies in higher education. Institutional policies should align academic timetabling with biological circadian rhythms by capping mandatory 8:00 AM lectures for high-workload programs, allowing adequate sleep recovery windows. Furthermore, student counselling services should integrate brief PSQI-based sleep latency and disturbance screeners into standard wellness intake assessments, identifying sleep-deprived individuals early for non-pharmacological Cognitive Behavioural Therapy for Insomnia (CBT-I) workshops.

Keywords: *Sleep Latency, Sleep Disturbance, Health-Related Quality of Life (HRQoL), Conceptual Framework, Theoretical Scaffolding, Higher Education Policy.*

1. Introduction and Background

Sleep is important for physical and mental recovery. It also helps maintain a balance in the nervous system. For students, sleep is also important for how well they are able to study, how well they are able to make choices, and how productive they are able to be. Research results show that persistent sleep problems for students are in the range of 10% to 50% of the population (Dinis & Bragança, 2019). Sleep is a big concern for students, and recent research shows that disrupted sleep is due to the new freedoms and new problems that are part of the on-campus experience. It is all a disruption to circadian rhythms. Sleeping well and being healthy are connected, and sleep reflects both (CDC, 2022). Historically, public health frameworks evaluated sleep health almost exclusively through volumetric parameters such as total sleep time (TST). However, empirical evidence demonstrates that sleep duration alone fails to capture functional daytime impairments. Modern behavioral medicine prioritizes qualitative sleep architecture—specifically quantifying sleep onset latency and neuro-somatic disruption frequencies—as these qualitative sub-domains directly dictate slow-wave restorative processes and subsequent Health-Related Quality of Life (HRQoL). These structural sleep parameters help create focused health system pathways within the academic environment.

Problem Statement

Of all the factors contributing to optimal physical, mental, and social functioning, sleep quality ranks high. For all age groups, worse sleep quality has been linked to all stages of several cardiometabolic disorders. In higher education, quality sleep becomes an even greater priority because chronic sleep deprivation adversely affects working memory, alertness, concentration, and social skills.

Reduced quality and quantity of sleep has been the subject of much research in the wake of the global health crisis it has precipitated. Chronic sleep deprivation is now considered a social norm amongst university students. The health of students is often disregarded for the sake of the institution's short-term benefit. This is commonly referred to as "student syndrome," where students poorly manage their time during the semester

and consequently leave themselves with a deadline constraining the time available to complete an academic task. This severely increases stress, worsens the quality of sleep, and increases sleep latency and sleep inconsistency.

Research into sleep as a public health concern has found that sleep deprivation has a negative impact on the ability to function during the daytime. Quality sleep must include the ability to complete several cycles without interruption of deep sleep and REM sleep. Lack of quality sleep has many psychosocial ramifications including pain in the muscles and skeleton during rest.

Some previous research has attributed poor sleep management to acute functional impairment. However, university health administrators have been presented with a different sort of challenge. At this point, almost no research has been done to identify which sleep parameters (i.e., sleep length, sleep onset latency/initiatives, sleep disturbance, etc.) are correlated with any aspects of Health-Related Quality of Life (HRQoL). Hypothesis testing will be conducted using Partial Least Squares Structural Equation Modelling (PLS-SEM) via SmartPLS. PLS-SEM is particularly appropriate for this study given its suitability for complex theoretical models with multi-item latent constructs and exploratory structural paths. The evaluation will proceed in two stages: assessing the measurement model (internal consistency reliability, convergent validity via AVE, and discriminant validity via HTMT criteria) followed by structural model estimation (β path coefficients, R^2 values, effect size f^2, and predictive relevance Q^2).

Bedtime procrastination, frequently driven by academic overburdening and poor time-management behaviors, serves as a primary behavioural catalyst for sleep onset latency (Foulkes et al., 2019). Rather than functioning merely as an acute scheduling delay, this self-regulatory failure initiates a state of prolonged pre-sleep overthinking and acute psychological distress. Over time, this acute state transitions into a chronic stress pattern, impairing autonomic nervous system regulation and locking students into persistent sleep deprivation cycles.

Probably the most significant hindrance to most systems of health for students is the historic and overwhelming domination of sleep as a self-contained measure of an individual's level of baseline wellness. By focusing predominantly or exclusively on total sleep hours, health systems for students fail to recognize the more insidious aspects of sleep disturbances, such as prolonged sleep onset cues and persistent macro- somatic rest and sleep disturbances. The combination of all these factors creates a three-dimensional theoretical challenge.

The Dynamics of Sleep Latency and Bedtime Cognitive Hyperarousal

The bedtime procrastination of some students leads to insurmountable physiological problems in shifting from an aware active daytime state to a restful nighttime state. The confluence of academic stressors, bedtime rumination, and screen-induced high-energy visible (HEV) light exposure triggers neurobiological hyperarousal. This state activates the hypothalamic-pituitary-adrenal (HPA) axis, elevating circulating cortisol and adrenaline while delaying melatonin onset. Consequently, the physiological shift from sympathetic dominance to parasympathetic restoration is disrupted, expanding Sleep Onset Latency (SOL) and deteriorating daytime cognitive functioning. The Sleep Onset Latency (SOL) is regularly and clinically set at a maximum of 30 minutes. Anything more has a negative impact on concentration, the ability to consolidate memory, and emotional stability. The erosion of these essential components contributes to a reduction in the HRQoL of students.

The Dynamics of Sleep Disturbance and Structural Sleep Stage Fragmentation

Students face a double whammy when it comes to the challenges of getting a good night's sleep. Not only do they face initiation barriers, but their sleep is still interrupted by a variety of physical and environmental challenges (e.g., their dorms). Sleep is frequently interrupted by a variety of disturbances (e.g., midnight wake-ups, breathing difficulties, coughing, unsettling dreams, and other muscle spasms). It becomes very difficult to achieve an optimum amount of Stage N3 Sleep (Slow Wave Sleep) and REM Sleep. Stage N3 Sleep is the sleep stage where the body undergoes its greatest restorative process, detoxifying the brain and cellular repair. If we are not able to reach that state of sleep consistently, we not only feel tired, but we also have weakened immune systems and deteriorating memory. Additionally, if dorm rooms cause drastic temperature changes,

going from too hot to too cold, sleep will be disturbed even further. This also causes our bodies to react in ways that increase heart rate and cause sleep stress. It is no secret that this stress and disturbed sleep get harder to cope with and negatively affect our quality of life.

The Deficiency of Evidence-Based Institutional Alignment

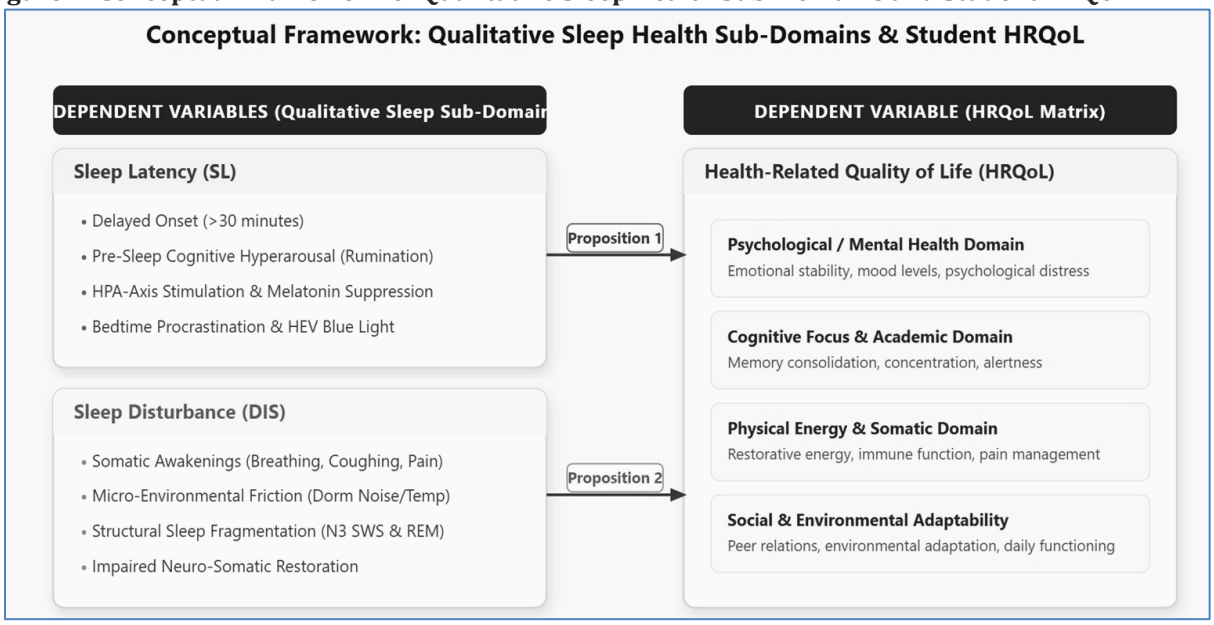
Measuring and analysing the Effects of Sleep Latency and Sleep Disturbance separately from the influences of Sleep Duration remain virtually impossible. In the absence of a clear framework, university administrators, the medical team, and even campus counselling services are compelled to undertake broad, non-evidence-based, in the best case scenario, less harmful practices, e.g., the improvement of soundproofing in students' halls. This is, however, only helpful if Sleep Disturbance is the result of outside noise. If the students are the cause of their own Sleep Latency because of extreme pre-bed annoying behaviours, including the use of digital gadgets (which are also a significant cause of AI stress and cognitive overload), then the new practices will not be helpful.

A significant theoretical gap persists regarding how specific qualitative sub-domains of sleep independently drive multidimensional HRQoL outcomes in undergraduate populations. By establishing a dual-axis framework—differentiating pre-sleep cognitive hyperarousal (latency) from neuro-somatic fragmentation (disturbance)—this model provides the theoretical scaffolding required to design evidence-based, non-pharmacological wellness interventions within higher education institutions. In this case, we hope to develop that theoretical model that allows us to deliver on our moral obligation to our students.

Proposed Conceptual Architecture & Propositions

The main purpose of the independent conceptual pipeline is to illustrate the direct links between sleep architecture and quality of life by employing a multi-disciplinary approach.

Figure 1: Conceptual Framework of Qualitative Sleep Health Sub-Domains and Student HRQoL



The proposed conceptual framework models Sleep Latency (SL), driven by bedtime cognitive hyperarousal and melatonin suppression, as well as Sleep Disturbance (DIS), driven by somatic discomfort and micro-environmental dormitory friction, as primary qualitative predictors of multidimensional Health-Related Quality of Life (HRQoL).

To direct future empirical validation and structural verification, two core theoretical propositions are advanced

Proposition 1
Sleep Latency resulting from pre-sleep cognitive hyperarousal, behavioural inhibition, and melatonin suppression negatively impacts cognitive focus and psychological satisfaction within the HRQoL framework.

Proposition 2
Structural sleep disturbances arising from somatic discomfort and micro-environmental friction inhibit sleep stage continuity, directly eroding physical energy, somatic recovery, and social adaptability within the HRQoL framework.

2. Proposed Methodology & Instrumentation Strategy

To empirically test this conceptual framework, a quantitative cross-sectional survey design will be employed (Wang & Cheng, 2020). The target population comprises full-time undergraduate business management students at Universiti Teknologi MARA (UiTM) Puncak Alam. Using Krejcie and Morgan's (1970) sample size determination matrix for a finite population, a minimum sample size of N = 196 will be recruited using a stratified random sampling technique to ensure proportional representation across different academic years and living arrangements (on-campus dormitories vs. off-campus housing).

Data will be collected using a structured, self-administered questionnaire divided into three distinct sections. All measurement items will be adapted from validated psychometric tools and evaluated on a standardized 5-point Likert scale ranging from 1 ('Strongly Disagree' / 'Never') to 5 ('Strongly Agree' / 'Always') to ensure measurement uniformity and simplify respondent processing.

Sleep Latency (Construct A) and Sleep Disturbance (Construct B) will be measured using 8-item sub-scales adapted from the Pittsburgh Sleep Quality Index (PSQI) sub-domain framework established by Shahid et al. (2011). To adapt these items from clinical diagnostic indicators into a student-facing survey, standard open-ended time entries (e.g., minutes taken to fall asleep) were converted into 5-point frequency items focusing on pre-sleep overthinking, delayed onset (>30 minutes), somatic pain, and micro-environmental temperature fluctuations.

Health-Related Quality of Life (Construct C) will be evaluated via an 18-item multidimensional matrix adapted from Jankovic et al. (2021), assessing physical energy, psychological state, peer relationships, and academic adaptability. Before full deployment, the complete instrument will undergo content validation by a panel of expert academic researchers and a pilot test (n = 30) to confirm item readability, face validity, and acceptable baseline reliability ($\alpha \geq .70$).

3. Theoretical Synthesis & Contemporary Literature Integration

To isolate the unique effect of sleep latency and sleep disturbance on HRQoL, potential confounding variables will be statistically controlled. The survey protocol will capture control metrics including daily caffeine consumption, self-reported diagnosis of clinical sleep disorders (e.g., obstructive sleep apnea), chronic medical conditions, and shift-work/part-time employment status. Respondents meeting clinical exclusion criteria will be filtered to maintain homogeneous non-clinical baseline parameters.

Sleep as a Physiological Imperative

Sleep is an essential homeostatic process and one of the three essential biological needs alongside food and water, occupying about a third of our total life. Studies in the field of neurology identify sleep as a prerequisite for the development and maintenance of the neural pathways needed for the consolidation of memories and the process of learning. The detrimental effects of lack of sleep on concentration, mental alertness, and the speed of reactions are well known. Cognitive and psychological health deteriorate with the deprivation of sleep, and physical health is likely to follow.

Dimensions of Sleep Quality and the Student Demographic

Subjective sleep quality refers to a person's perception of their sleep and how they experience the quality of their sleep. Sleeping well has a myriad of benefits. Daytime alertness, improved reflexes, and enhanced

interpersonal relations are a few. Poor sleep quality, on the other hand, is associated with chronic fatigue, poor and erratic productivity, impaired cognition, and unhealthy coping habits, such as increased caffeine intake or increased alcohol consumption. University is the most damaging to the quality of people's sleep; students are at the highest risk of all demographics for developing sleep disorders. Studies show that the mental health of 10 to 50% of the student population is negatively impacted due to poor sleep quality. There is a lot of stress and lifestyle changes that occur during the high school-to-university or high school-to-work gap. These changes are often deleterious to health and detract from academic performance.

Conceptualizing Health-Related Quality of Life (HRQoL)

Examining sleep in conjunction with existing health constructs can help to understand the implications of sleep deprivation more broadly. The World Health Organization (WHO) states that Quality of Life (QoL) is the way individuals assess their position in the world, considering their cultural contexts and value systems and their personal goals. Narrowing it down, Health-Related Quality of Life (HRQoL) concerns how individuals assess their mental and physical health at different times. HRQoL is a diverse construct that combines physical, psychological and social domains of well-being and is an essential construct for valuing health interventions directed at students.

The Dynamic Interaction Between Sleep Volume, Academic Outcomes, and QoL

It is clear that sleep impacts academic success in higher education. While some studies may report small effects, most studies agree that the quantity and especially the quality of sleep impact success in higher education, measured as a higher GPA and better learning engagement. In the National Sleep Foundation's study, adults 18-64 should receive 7 to 9 hours of sleep, while older adults should receive 7 to 8 hours of sleep. Sleep quantity and especially sleep quality impact quality of life. Poor sleep quality also impacts daily functioning. Positive daytime experiences are a result of good quality sleep. Good quality sleep is associated with greater life satisfaction, better mental health, and reduced work stress and poor sleep quality is associated with reduced life satisfaction.

Determinants of Sleep Interruption: Technology and Academic Pressure

Current lifestyle habits pose significant challenges to the sleep hygiene of young adults. A major reason for disrupted sleep is the widespread habit of going to sleep with electronic devices. This habit reduces total sleep hours and disrupts the circadian cycle. Using mobile devices within 30 minutes of going to sleep increases the risk of serious sleep disruptions. Personal habits are not the only reason for disrupted sleep. There are also sleep-inhibiting factors that result from the pressure of classroom instruction and academic demands on most young adults. The long-term effects of stressful events, such as the COVID-19 pandemic, show that stressful academic years can deteriorate to the level of clinical anxiety and psychological distress. Insufficient and non-restorative sleep elevates the negative effects on young adults which manifests as sleep-related deficits in the ability to focus, concentrate, and endure any sustained mental effort and work during their daytime scholarly activities.

Sleep Latency: The Tri-Axis Mechanics of Cognitive Hyperarousal and Melatonin Suppression

Behavioral architecture has recently examined sleep problems and discovered that long sleep onset latency (SOL) is more than just a neurobiological problem that alters sleep. It can be broken down into three components: Sleep Time Displacement, Melatonin Suppression due to High-Energy Visible (HEV) Blue Light, and Pre-Sleep Cognitive Hyperarousal. The Pre-Sleep Cognitive Hyperarousal factor is the most relevant in higher education, as the leading contributor to this factor is students' excessive use of their smartphones to view social media (or other forms of digital) content right before going to sleep (Zhang et al., 2025). Beyond basic behavioural procrastination, the prolonged initiation phase in student populations can be understood through the lens of Harvey's (2002) Cognitive Model of Insomnia. Pre-sleep intrusiveness—characterized by anxious rumination over academic deadlines—initiates a cascade of emotional distress and physiological hyperarousal. This autonomic activation directly opposes the somatic relaxation required for sleep onset, confirming that latency is predominantly a cognitive-emotional dysfunction rather than a simple scheduling failure.

Cognitive stimulation right before sleep is an important factor in delaying the release of melatonin from the pineal gland due to blue light. The HPA axis is then activated and the resulting overproduction of cortisol and

adrenaline prevents the most critical and necessary transition of the autonomic nervous system from being dominated by the sympathetic nervous system (or fight or flight) to being dominated by the parasympathetic nervous system (or rest and digest). The cumulative effect of the Pre-Sleep Cognitive Hyperarousal, Melatonin Suppression, and Sleep Time Displacement components has recently been shown to adversely impact the processes of sleep in the brain. Researchers have indicated that this deficit negatively impacts emotional regulation and has been associated with a 25% decrease in subjective well-being.

Based on our framework, Sleep Latency is likely to undermine psychological and cognitive satisfaction within the relevant HRQoL matrix.

Sleep Disturbance: The Neuro-Somatic Fragmentation Matrix and Macro-Environmental Friction

To fully evaluate its theoretical contribution, sleep disturbance must be analyzed through a comprehensive neuro-somatic fragmentation matrix rather than treated simply as isolated, ill-defined nighttime awakenings. Modern behavioral medicine recognizes structural sleep fragmentation as being characterized by recurrent micro-arousals and physical discomfort stemming from nighttime temperature fluctuations, respiratory disruptions, and somatic pain. This continuous fragmentation disrupts the natural architecture of the sleep cycle, truncating the duration and depth of both Stage N3 Slow-Wave Sleep (SWS) and Rapid Eye Movement (REM) sleep. Because Stage N3 sleep is essential for human growth hormone (HGH) secretion, cellular repair, and neuro-immunological restoration, persistent disruptions within this phase severely undermine systemic physical recovery.

Empirical literature demonstrates a strong bidirectional association between structural sleep fragmentation, psychological distress, and academic burnout among student populations (Zhang et al., 2025). While nocturnal micro-awakenings deplete physical energy and impair daytime coping mechanisms, elevated daytime stress conversely heightens baseline sympathetic tone at night. This bidirectional feedback loop transforms acute environmental disruptions into chronic neuro-somatic distress, exponentially deteriorating long-term HRQoL sub-domains. Once structural sleep continuity is broken, daytime fatigue increases, and the body's baseline physiological stress response to environmental demands becomes significantly heightened.

Recent environmental and public health research has increasingly emphasized the role of dormitory micro-environments in regulating circadian architecture. Thermal discomfort and ambient noise in shared student housing disrupt thermoregulation—specifically preventing the physiological drop in core body temperature necessary to sustain Stage N3 slow-wave sleep. Consequently, macro-environmental friction directly triggers autonomic micro-arousals, truncating deep restorative sleep independent of individual sleep hygiene behaviors. Suboptimal room conditions and poorly insulated student housing—where ambient temperatures fluctuate drastically between extremes—cause nocturnal cardiac acceleration and autonomic arousal responses. Ultimately, the physical strain induced by structural sleep fragmentation serves as a primary depressor of physical functioning, social engagement, and environmental adaptability within the HRQoL domain matrix.

4. Strategic Institutional Design & Future Research Direction

The Strategic Independent Qualitative Model provides a framework for higher education system designers interested in specific kinds of wellness interventions. These include:

Digital Cognitive Interventions

Rather than relying on passive wellness flyers, campus health centers should implement targeted digital hygiene protocols to mitigate bedtime cognitive hyperarousal. University IT and academic systems can support this by establishing automated Learning Management System (LMS) quiet zones—restricting assignment submission deadlines to 8:00 PM rather than midnight—and integrating evening 'screen-down' prompts across student portals 30 to 60 minutes before scheduled dormitory quiet hours.

Macro-Environmental Dormitory Design

University facilities management can utilize the Sleep Disturbance sub-axis to implement concrete structural upgrades in student housing. Key micro-environmental interventions include installing programmable

nocturnal thermostatic controls to maintain optimal sleeping ambient temperatures (18°C–21°C), retrofitting hall windows with high-grade acoustic insulation to minimize micro-awakenings, and utilizing low-kelvin warm LED lighting in communal hallways to reduce circadian melatonin suppression.

Statistical Model Expansion for Future Research

Those interested in advancing the work presented in this model will have a strong starting point. The model conveniently allows for hidden mediator blocks to be inserted. Future studies related to the model may include unmeasured variables such as academic workload pressure and Pre-bedtime Screen-Time Hours of students to gain a better understanding of student wellness.

5. Conclusion

This conceptual paper advances a streamlined theoretical framework positioning Sleep Latency (SL) and Sleep Disturbance (DIS) as distinct, qualitative predictors of Health-Related Quality of Life (HRQoL) among university students. By shifting the public health paradigm away from crude, volumetric sleep metrics (such as total sleep hours) toward structural qualitative sub-domains, the model demonstrates strong conceptual clarity and content validity. It effectively bridges neurobiological mechanisms, including pre-sleep cognitive hyperarousal, HPA-axis activation, and slow-wave sleep fragmentation with multidimensional student well-being. However, formal empirical construct validity, evaluated through convergent and discriminant validity testing, remains to be statistically confirmed upon field data collection.

Beyond its theoretical contributions, this framework provides higher education administrators and student affairs professionals with a structured, evidence-informed foundation for designing targeted, non-pharmacological interventions. By recognizing that sleep latency is largely driven by pre-sleep overthinking and digital blue-light exposure, university leaders can implement structural academic adjustments, such as enforcing earlier LMS assignment submission deadlines and establishing late-night digital quiet hours. Concurrently, addressing sleep disturbance requires macro-environmental campus housing upgrades, including nocturnal thermostatic controls and soundproofing, to eliminate physical micro-arousals during deep sleep stages.

Ultimately, prioritizing qualitative sleep health is essential for fostering resilient, high-performing academic communities. While future empirical research is necessary to confirm the structural path coefficients and test for underlying behavioral mediators, this study establishes that protecting student sleep quality is a fundamental prerequisite for optimizing health-related quality of life and long-term academic success.

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EcoTacToe Digital Gamification In Education: A Cross-Sectional Study

*Azhan Rashid Senawi[1], Shariff Harun[1], Mohammad Zulfakhairi Mokhtar[1], Husna Husain[2], Li Shuang[3], Nik Musri Erwan Eddy Nik Mustapha[4]
[1]Circular Economy of Logistics & Operations (CELO) RIG, Faculty of Business & Management, Universiti Teknologi MARA, Selangor, Malaysia
[2]Faculty of Human Sciences, Universiti Pendidikan Sultan Idris, Perak, Malaysia
[3]Tourism Humanities, Heilongjiang Polytechnic, China
[4]Ikhasas Sdn Bhd, Malaysia
Email: *azhanrashid@uitm.edu.my, shariffharun@uitm.edu.my, zulfakhairi@uitm.edu.my, husnahusain@fsk.upsi.edu.my, lishuang789123@gmail.com, nik.musri@accor.com
Corresponding Author: Dr Azhan Rashid Senawi

Abstract: Econometrics is a discipline requiring considerable mathematical competence and sophisticated analytical ability, yet standard teaching approaches may not always provide the necessary engagement for effective learning. Digital gamification is a new instructional style that bridges this gap. This study explores students' perceptions of EcoTacToe, a digital gamification application similar to the game of TicTacToe, designed to enhance Econometrics teaching in terms of competition and interaction. A quantitative cross-sectional methodology was employed to recruit 86 undergraduate students from a Malaysian public university. A systematic self-administered questionnaire measuring five dimensions: personal traits, acceptance, utility, enjoyment and user-friendliness was used to collect data. Reliability analyzes confirmed internal consistency for all constructs, with coefficients ranging from α = .75 (Good) to α = .93 (Excellent). Descriptive analyzes revealed predominantly positive appraisals across all variables, with enjoyment reaching the highest average, followed by simplicity of use and utility. Independent samples t-tests indicated no significant differences between male and female students on any dimension. The findings demonstrate that EcoTacToe is an effective blend of competitive gaming with the distribution of Econometrics material, and a practical addition to regular classroom education.

Keywords: *Digital Gamification, Econometrics Education, App-Based Learning, Higher Education, Malaysia, Technology Acceptance Model*

1. Introduction and Background

Econometrics is important to quantitative analysis in business and economics courses, including the statistical tools needed for empirical research and the analysis of applicable data. The quantitative nature of the subject makes it especially difficult for many undergraduates and standard lecture-based teaching approaches have always failed to motivate students and to help them to apply what they have learned (Deterding et al., 2011; Zeng et al., 2024). This has led to universities and colleges exploring innovative teaching methods that involve hands-on experience.

The word "gamification" – the use of game concepts in a non-gaming context – has recently become popular (Deterding et al., 2011). Gamification, which involves injecting competitive elements, instant feedback, and goal-setting structures into the learning atmosphere, has been found to enhance motivation, engagement, and recall of material in many educational situations (Zeng et al., 2024; Gyedu et al., 2026). This is not just the case for general education but also analytically heavy subjects such as statistics, supply chain management and logistics education, as demonstrated in recent studies (Jack et al., 2025; Sundram et al., 2025; Kasdi et al., 2025).

EcoTacToe is a mobile app game based on the TicTacToe format, serving as a fun tool for learning Econometrics. The game puts difficult econometrics concepts into grid placements, gamifying otherwise ethereal quantitative concepts. It has been implemented in schools, but we have little data on how it has helped kids learn or how students have responded.

This study is based on five thematic constructs namely, personal traits, acceptability, utility, enjoyment and ease of use. These constructs are intended to measure students' perceptions of EcoTacToe. This study contributes to the increasing body of literature on digital gamification to enhance quantitative education in

Malaysian universities. This study is based on the Technology Acceptance Model (TAM) framework (Davis, 1989) and accepted personality traits (Costa & McCrae, 1992).

2. Literature Review

Around the world, education systems are under increasing pressure to make sure that graduates are equipped with the analytical and problem-solving abilities that modern economies demand, as well as theoretical knowledge. Malaysia's national policy frameworks place importance on producing highly trained graduates to satisfy the needs of Industry 4.0. This only highlights the need for new, hands-on approaches to learn mathematical subjects even more.

In the last few years, gamification has been one of the most studied new methods of teaching. Zeng et al. (2024) compiled results of 22 experimental investigations from 2008 to 2023 and concluded that gamification had a positive and significant influence on students' academic performance compared to non-gamified environments. These findings are corroborated by the meta-analysis by Gyedu et al. (2026) on higher education contexts which found gamification to be beneficial for student engagement as well as deep learning outcomes. All these data show that gamification is not only a means to increase motivation but a real element influencing the quality of learning.

In quantitative disciplines — where student disengagement is a recurring challenge — gamification has demonstrated particular promise. Jack et al. (2025) investigated the integration of gamified elements in a flipped statistics classroom and found that gamification significantly elevated pre-lecture engagement rates and was associated with improved academic grades. These findings suggest that gamified elements can meaningfully raise engagement in subjects that students often perceive as difficult or demotivating, a challenge directly analogous to the Econometrics context of the present study (Senawi & Harun, 2025).

The studies on gamification at Malaysian institutions have increased in recent years with a focus on the management and business courses. Hoo et al. (2024) explored the use of card games and board games for teaching supply chain management principles in Malaysian universities. The results indicated that the two game styles were excellent for students' involvement and learning outcomes. Following this work, Sundram et al. (2025) explored game-based approaches for the teaching of supply chain management and found uniformly positive effects on student motivation and course participation. Kasdi et al. (2025) conducted a quasi-experimental study to investigate the analog game Logispreneur 101 for logistics education. They found that the competitive characteristics, collaborative nature, and decision-making tasks of the game had a significant impact on the enjoyment and perceived learning of students. To summarize, the research supports the notion that gamification might be beneficial in the analytically challenging domains of business education in Malaysia.

The dominant theoretical model for assessing students' acceptance of instructional technology is the Technology Acceptance Model (TAM), initially proposed by Davis (1989). TAM says the two most essential variables that determine whether technology is accepted and employed are usefulness of the technology and ease of use. As hedonic experiences are important in long-term technology adoption, particularly in gamified learning contexts, Venkatesh (2000) extended this framework to incorporate intrinsic drive and subjective enjoyment as additional determinants.

Personality traits have been shown to be important mediators of gamification acceptance as well. According to the model of personality traits, the Big Five (Costa and McCrae, 1992), openness to experience and the wish to acquire new information are closely related to the person's willingness to embrace new educational technologies. The five-construct model of this study is theoretically sound, founded in the TAM framework and the personality trait theory.

While there is an increasing number of studies on gamification, the application of digital gamification in the teaching of econometrics remains underexplored, especially in the Southeast Asian educational context. This research is a direct answer to the requirement for the first comprehensive empirical assessment of EcoTacToe's educational reception.

3. Research Methodology

This study aimed to evaluate EcoTacToe, a digital gamification tool for teaching Econometrics, from the students' point of view through a quantitative correlational research approach. The target population comprised three classes of undergraduates taking Econometrics at the same public university in Malaysia. Respondents were selected via non-probability purposive sampling, where the respondents were already exposed to the EcoTacToe app in the classroom.

Primary data were collected using structured self-administered questionnaires with five-point Likert scales. According to Zikmund et al. (2000), the Likert scale is a reliable measure of people's openness to a topic. One was for strongly disagree, two was for disagree, three was neutral, four was for agree and five was for strongly agree. We got 86 relevant replies. The nineteen items in the questionnaire were organized into five theme constructs, which are listed in Table 1.

Table 1: Thematic Constructs Analysis.

Constructs	Items	Measure
Personal Traits	3	Openness to adventure and new learning experiences
Acceptance	4	Perceived advantages of the EcoTacToe app game versus conventional instruction
Usefulness	6	Impact of EcoTacToe on Econometrics understanding, learning efficiency, and academic productivity
Enjoyment	3	Entertainment and fun aspects of EcoTacToe gameplay
Ease of Use	3	Interface clarity, gameplay rules, and usability

The structures were modified according to the existing theoretical frameworks. We have employed Personal Traits, Usefulness and Acceptance constructs of Costa and McCrae (1992), Ease of Use and Davis (1989), and the Enjoyment construct of Venkatesh (2000). SPSS was used to conduct descriptive statistics, internal consistency analysis (Cronbach's Alpha) and t-tests for independent samples to test for differences in perception by gender.

4. Results

All examined constructs were perceived positively based on data analysis from 86 undergraduates who participated in the EcoTacToe gamification intervention. Table 2 provides the demographic characteristics of the participants.

Table 2: The Respondents' Demographic Profiles.

No.	Categories of Demographic Variables	Frequencies	%
1.	**Gender**		
	Male	34	39.5
	Female	52	60.5
2.	**Age**		
	20 – 22	14	16.3
	23 – 25	70	81.4
	26 – 28	1	1.2
	32 or older	1	1.2

The reliability test was conducted on the variables to determine the internal consistency of the constructs. The measurement scale by Zikmund et al. (2000) was employed in this study, which states: Reliability is Excellent when $\alpha < 1.0$, Very Good when $\alpha < 0.89$, Good when $\alpha < 0.70$, Fair when $\alpha < 0.69$, and Poor when $\alpha < 0.60$. Table 3 shows the Cronbach's Alpha of each construct.

Table 3: Cronbach's Alpha and Reliability Analyses.

Variables	Items	Cronbach's Alpha	Indicator
Usefulness	6	.93	Excellent Reliability
Enjoyment	3	.90	Very Good Reliability
Ease of Use	3	.88	Very Good Reliability
Acceptance	4	.87	Very Good Reliability
Personal Traits	3	.75	Good Reliability

Reliability evaluations indicate that all constructs have Cronbach's Alpha between .93 (Excellent) and .75 (Good), which is an indication of appropriate internal consistency and stability of measurement. All constructs are above the minimum acceptable requirement of .70; the measurements are dependable and suitable for further inferential investigations.

Table 4 presents the mean values and standard deviations of each construct in descending order.

Table 4: Descriptive Statistics of Constructs.

Variables	Mean	Standard Deviations
Enjoyment	4.10	0.61
Ease of Use	4.09	0.61
Usefulness	4.08	0.61
Personal Traits	4.03	0.53
Acceptance	3.94	0.62

The descriptive analyzes indicated that four of the five constructs had means over 4.00, which demonstrates that the students' attitudes toward EcoTacToe were highly positive. Learning econometrics was really fun and motivating with the competitive TicTacToe-format games, as indicated by the highest mean (M = 4.10, SD = 0.61) for enjoyment. Ease of Use (M = 4.09, SD = 0.61) was second place, and it showed that students considered the rules of gameplay to be easy, the interface of the program was clear, and the program was easy to use. Usefulness (M = 4.08, SD = 0.61) was the third most important factor. This showed that respondents considered EcoTacToe as a beneficial instrument for mastering the fundamentals of econometrics, increasing academic productivity and improving learning efficiency. Personal Traits had a mean of 4.03 (SD = 0.53) suggesting that gamified learning was a good fit with the sample's adventure-seeking orientation and openness to new experiences . Acceptance was the lowest-ranked idea, but it was positive (3.94; SD = 0.62) indicating that students generally perceived the benefits of interactive app games instead of traditional teaching techniques.

Gender based differences in perception for each idea were tested by independent-samples t-tests. Results indicated a non-significant difference was found between male and female students in all dimensions ($p > .05$). Specific results are enjoyment [$t(84) = -0.924$, $p = .358$], ease of use [$t(84) = 0.108$, $p = .914$], usefulness [$t(84) = -1.051$, $p = .296$], personal traits [$t(84) = 0.886$, $p = .378$], and acceptability [$t(84) = 0.224$, $p = .823$]. EcoTacToe was equally enjoyable, practical and accessible for male and female pupils.

5. Discussion and Recommendations

The results of the current research validate EcoTacToe as an effective digital gamification tool for Econometrics instruction, since students always show positive perceptions in all five measured categories. These findings are consistent with the extensive research on gamification which has demonstrated that well-designed game-based learning aids can improve students' engagement and motivation in higher education (Zeng et al., 2024; Senawi et al., 2025, Gyedu et al., 2026).

It is particularly important that enjoyment (M = 4.10) is the highest-rated concept. This lends support to the claim made by Venkatesh (2000) that perceived enjoyment is an important antecedent of technology adoption, especially for applications where user satisfaction is a driving factor. Competitive EcoTacToe, in which students answer econometrics questions to "own" grid positions, seems to tap into innate motivation via goal-oriented competition and challenge. This finding is consistent with Jack et al. (2025) who found that gamified features in a statistics course led to prolonged engagement since they made the learning process fun rather than tedious.

The high ranking for ease of use (M = 4.09) highlights a basic design guideline for the adoption of instructional technology: complexity is a disincentive. The students' perception that the UI was intuitive, the rules of the game were clear and the program was generally accessible supports Davis's (1989) TAM premise that perceived ease of use is a significant factor in technology acceptance. EcoTacToe's easy TicTacToe gameplay seems like a plus over the more complex simulation-based platforms. This reduces the cognitive threshold to participate, and enables students to concentrate on the econometrics subject, not on how to navigate the site.

The usefulness of EcoTacToe (M = 4.08) is a sign that students believe that it has a substantial contribution to their Econometrics learning goals. This is particularly remarkable as Econometrics normally requires knowledge of arcane statistical methods, regression analysis, and hypothesis testing. Students also commented that the game helped in understanding these concepts . Thus, the question and answer gameplay mechanisms were able to operationalize knowledge from the course in a way that was accessible and helped with retention. This finding is consistent with the findings of Sundram et al. (2025) and Kasdi et al. (2025) who found that gamified tools with discipline-specific content yielded perceived utility in supply chain management education, an analytically comparable field.

Although the acceptance construct (M = 3.94) had the lowest mean score among the five constructs, it was still above the scale midpoint of 3.00, indicating a positive disposition. This construct examines the perceived pros of EcoTacToe compared to normal education. This result reveals that although students favor gamified approaches in general, a minority of them still appreciate traditional instructional elements. This outcome is not surprising considering 96.5% of the sample had previous experience with instructional games and 75.6% played just sometimes. Therefore, for most responders gamification is a secondary, not a primary, form of learning. Over time, consistent and prolonged use of gamified learning technologies may increase adoption.

The lack of statistically significant gender differences across all dimensions ($p > .05$) is consistent with the results of similar gamification investigations (Kasdi et al., 2025; Hoo et al., 2024). This corroborates that EcoTacToe is an educational tool that is appropriate for varied classroom groups because it attracts a wide student demography irrespective of gender.

This work has many limitations that should guide future research directions. The cross-sectional design does not allow us to conclude on long-term engagement trajectories or sustained academic success as it gathers perceptions at one point in time. Secondly, the intentional sampling from one public institution limits the generalizability of the findings to other student demographics and institutional situations. For example, the demography of students and the educational culture present in private colleges may be different from that of public universities, hence, perceptions of gamified tools may also differ. Also, future research should use longitudinal designs and widen the sample to multiple universities to boost external validity. Further strengthening the evidence base would include experimental or quasi-experimental designs that clearly compare EcoTacToe to traditional training on assessed academic outcomes.

However, this study provides a relevant and scientifically substantiated assessment of digital gamification in the domain of economics education. The combined good perceptions of all five dimensions and the non-existence of gender differences strongly justify the use of EcoTacToe as a supplement to traditional Econometrics teaching.. EcoTacToe would be an attractive proposition for educators and institutions looking to augment their curricula with pedagogically sound, interesting and accessible tools. Well-designed digital gamification tools like EcoTacToe can be innovative tools for bridging the divide between traditional classroom education and the interactive, practical learning experiences that are demanded by today's undergraduate students.

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Evaluating Consumer Acceptance of Medical Repricing in Malaysia: The Role of Fairness, Transparency, Trust and Health Insurance Literacy

*Mohd Faizol Rizal Mohd Rasid[1], Ainol Fizy Ruslan[1], Nurul Hidayah Zainal[1], Ahmad Al-Amin Faisal[1], Muhammad Hafiz Marzuki[2], Nurul Farehah Anuar[3]
[1]Faculty of Business and Management, Universiti Teknologi MARA, Cawangan Selangor, Kampus Puncak Alam, Selangor, Malaysia
[2]Faculty of Business and Accountancy, University Poly-Tech Malaysia
[3]Etiqa Family Takaful Berhad, Malaysia
Email: *faizolrizal@uitm.edu.my, ainolfizy@uitm.edu.my, nurulzainal@uitm.edu.my, ahmadalamin@uitm.edu.my, muhammad_hafiz@uptm.edu.my, nfarehah.a@etiqa.com.my
Corresponding Author: Mohd Faizol Rizal Mohd Rasid

Abstract: This study examines the structural impact of perceived fairness, transparency, institutional trust and health insurance literacy on public acceptance of medical insurance repricing in Malaysia. Against the backdrop of compounding medical inflation in an emerging economy, existing literature has predominantly focused on Western employer-based systems, leaving an empirical gap regarding individual Medical and Health Insurance/Takaful (MHIT) policyholders in Southeast Asia. Utilizing a quantitative, cross-sectional design, primary data were gathered from 100 middle and upper middle-class policyholders in Puncak Alam, Selangor. Multiple Linear Regression analysis was conducted to evaluate the hypothesized relationships (β, t, p, R^2, VIF). The findings reveal that perceived fairness (β=0.312, p<0.001) and institutional trust (β=0.285, p <0.005) exert the strongest direct effects on policyholder acceptance of repricing, while health insurance literacy and transparency serve as vital structural precursors. The proposed model accounted for a significant proportion of variance in repricing acceptance (R^2=0.548, F=28.78). These empirical insights demonstrate that long-term pricing sustainability and policyholder retention depend not only on actuarial solvency, but also on transparent communication frameworks and regulatory anchors.

Keywords: *Medical Insurance Repricing, Fairness, Transparency, Trust, Health Insurance Literacy*

1. Introduction and Background

One of the new challenges and a significant burden for customers and insurance companies globally is the high cost of healthcare. The recent forecasting of macroeconomic variables suggests a compounding trend of the worldwide medical trend rate from 10.0% in 2025 to 10.3% in 2026 (WTW, 2025). The Asia-Pacific region is the frontrunner of this wave, as the medical inflation rate is expected to reach as high as 14% in 2026, some of the highest in the world (WTW, 2025).

According to Aon's 2025 research forecast, the medical trend rate for the Asia Pacific region is expected to be 11.3% of the trend in 2026. The rise in chronic clinical conditions, the high cost of the healthcare workforce, rapid development of medical technologies and the launch of high-cost drugs are the four structural forces driving this ongoing growth post-pandemic and they are backed by the 2025 research by Willis Towers Watson (Aon, 2025; WTW, 2025).

The Medical and Health Insurance and Takaful (MHIT) sector is badly hit by this hyper-inflationary trend in Malaysia. The Life Insurance Association of Malaysia (LIAM) in conjunction with the Malaysian Takaful Association (MTA) and the Malaysian Insurans Am Association (PIAM) highlighted the shocking spike in healthcare claims costs of 56% from 2021 to 2023 (Life Insurance Association of Malaysia (LIAM), 2024). Insurers or takaful operators have begun to aggressively reprice takaful premiums in a bid to maintain their solvency and capital adequacy. For some takaful policyholders, the increase in takaful premiums has been more than 30% (Life Insurance Association of Malaysia (LIAM), 2024; Malaysian Takaful Association, 2024). Alarming public concern about the affordability, transparency and equity of private health plans has led to these dramatic shifts.

Although employer-sponsored cost-sharing schemes are the focus of the current international literature, individual voluntary MHIT riders are the main feature of the Malaysian healthcare financing system. Consumer

awareness was analyzed in the motor insurance sector by Mohamad Basir et al. (2025), in the travel insurance sector by Ruslan & Mohd Rasid (2024), and in the property insurance sector by Ruslan et al. (2025). There is, however, a critical gap in empirical literature that has yet to examine the relationships between behavioral constructs and consumer acceptance in the context of acute medical repricing events, namely fairness, transparency, trust and health insurance literacy.

In late 2024, Bank Negara Malaysia (BNM) decided to take a proactive measure after the negative public sentiment and market volatility, by putting in place regulatory interim measures. To ensure that premium changes are implemented over a minimum of three years, with 80% or more of the policyholders affected experiencing premium changes of less than 10% per year (Bank Negara Malaysia, 2024). In addition, Bank Negara Malaysia imposed a repricing freeze for policyholders of minimal plans who are aged 60 and above and have low income, and a requirement to provide affordable options by the end of 2025 for the existing plans through the MHIT by policyholders (Bank Negara Malaysia, 2024). These interventions align with the overall system-wide health interventions set out as part of the Health White Paper by the Ministry of Health Malaysia (2023).

To systematically examine these dynamics, this study integrates Organizational Justice Theory and Cognitive Load Theory to evaluate the relational impacts of perceived fairness, transparency, institutional trust, and health insurance literacy on policyholder acceptance of medical insurance repricing.

2. Literature Review

Public Acceptance of Medical Insurance Repricing

Escalating medical trend rates in the global and regional economies are an integral part of the phenomenon of premium repricing. Recent data show that medical inflation has increased to 10.3% globally, and the Asia Pacific (APAC) region is seeing a sharp increase, with a projected increase of 14.0% (WTW, 2025).

The phenomenon is very strong in Malaysia. A remarkable 56% surge in healthcare claims costs was reported by the Life Insurance Association of Malaysia (LIAM), the Malaysian Takaful Association (MTA) and Persatuan Insurans Am Malaysia (PIAM) in a span of just two years (LIAM, 2024). The Bank Negara Malaysia (BNM) also confirmed that medical insurance claims have always been higher than premiums, which has led to cyclical structural pricing adjustments being a common actuarial practice to limit institutional insolvencies (World Bank, 2026).

A consumer's willingness to bear cost increases is one of the most important behavioural measures of perceived fairness. Research in consumer psychology suggests that price hikes will be resisted quite strongly if the consumer feels the company is taking advantage of existing market conditions to squeeze out higher profits (Aon, 2025). The Malaysian Public Accounts Committee (PAC) also noted that cyclically delayed repricing has left the policyholders with multiple and drastic premium shocks ranging from 40% to 70% within a short span of time (FMT News, 2026). These high adjustments violate the "affordable protection" part of the psychological contract and erode the consumer's sense of distributive justice substantially.

Transparency means there is an explanation of why the premium is increasing. One of the key problem areas with consumer hassles in Malaysia is the unclear billing systems of the private healthcare providers. The Parliament's PAC investigation showed that private hospitals are raising non-professional fees, such as the cost of pharmaceuticals and medical consumables up to 300% to subsidise other expenses (FMT News, 2026). Consumer acceptance drops sharply if these hidden costs are not itemized on insurers' bills. Transparent about the drivers of these costs is essential to ensure that consumers don't become frustrated (Prudential Malaysia, 2025a).

Trust is a buffer when the economy corrects itself. In the financial context, consumer trust is dyadic which is trust in the commercial provider to set product prices fairly and trust in the top regulator (Bank Negara Malaysia) to oversee market activities fairly. The structural interim relief measures introduced by BNM, which involve staggering premium changes from 2024 to 2026 over a minimum of three years, to ensure that 80% of policyholders are not subject to premium increases of more than 10% per year, provided an important

regulatory safeguard to maintain trust in the system at a high level and avoid mass policy lapses (Bank Negara Malaysia, 2024; World Bank, 2026).

Health insurance literacy is defined as the consumer's understanding of a risk pool, deductibles, co-payments and how medical inflation works. While this is the case in developed markets, it is not in emerging markets such as Malaysia. In Malaysia, there is an ongoing "savings account misconception" that consumers mistakenly believe they won't have to pay a premium because they have been paying no claims for a lifetime. Low rates of acceptance and high public resistance are linked directly to a lack of understanding of the effects of moral hazard, over-utilization, and unbundled hospital fees on a collective risk pool (World Bank, 2026)

There has been a significant empirical gap in the ASEAN region on behavioral health economics highlighted in recent policy studies. Employer-sponsored cost-sharing schemes are widely used in Western markets while the Malaysian market is dominated by individual Medical and Health Insurance and Takaful (MHIT) riders. To bridge the gap between financial viability and public acceptance, the Malaysian Government has been able to push for legislation that will take financial sustainability and public acceptance into consideration, including mandatory co-payment product variations and the proposed medical plan standardization in 2027 with a “base” plan that will remove luxury unbundled charges (FMT News, 2026; World Bank, 2026).

Perceived Fairness and Acceptance of Repricing.

Perceived fairness is an individual's psychological evaluation of a change in price that is not considered to be exploitative but reasonable, equitable and acceptable (Kahneman et al., 1986). From the perspective of contractual health insurance, fairness is realized in three different ways from an organizational justice perspective including distributive, procedural, and interactional.

Recent academic research and institutional reports highlight the need for an important paradigm shift in the dynamics of behavioral insurance, where the responses of consumers to premium changes are driven by psychological anchors rather than by actuarial logic. Specifically, Ben Amor et al. (2024) synthesized these behavioral dynamics to find that the perceived equity and systemic fairness of premium increases consistently outweigh the mathematical accuracy of the premium.

The psychological anchoring of price fairness perceptions has been further substantiated by the work of Zhang and Zhao (2024), who showed that price fairness perceptions are one of the most important psychological anchors, which then shapes whether a customer accepts a contractual price change or actively initiates a price change. Therefore, rate change as assessed by the consumer is far more important than it is substantiated by the empirical evidence when it comes to retention.

Recent industry reports underscore that structural transparency and contextualized communication are critical to mitigating policyholder friction. According to Aon (2025), escalating global medical trend rates have compelled insurers to mathematically justify underlying cost-push factors to maintain pricing legitimacy. Translating these actuarial drivers into accessible, consumer-centric terminology significantly reduces consumer resistance.

Supporting this, WTW (2025) demonstrates that explicitly linking price increases to macroeconomic indicators (such as the rising costs of pharmaceuticals and advanced diagnostics) substantially dampens public resentment toward structural rate adjustments.

On the other hand, without this context, price differentials are extremely risky from the perspective of consumer justice, which is a principle of distributive justice, as an empirical study on the World Bank health database, with global scope, confirms World Bank (2026). Combined, these results suggest that price transparency and fairness are as significant to sustainable insurance pricing as is actuarial solvency.

Structural Transparency and Acceptance of Repricing.

Transparency reflects structural clarity and granularity in explaining adverse financial drivers, mitigating the historical information asymmetry that leaves healthcare consumers vulnerable to opportunistic repricing.

There is a developing body of research highlighting how structural transparency and granular disclosure of data can be used to systematically dampen the rising conflict around healthcare insurance premium reviews. The Khazanah Research Institute (2024) revealed that the public's resistance to premium reviews had more to do with lack of clarity on the structures of hospital billing than with an outright rejection of cost adjustments.

There is also good empirical evidence in the local context such as Prudential Malaysia(2025a), where the direct correlation between their publication of itemized medical repricing rationales and reduced consumer friction and significant improvement in policy retention rates is a strong reinforcement of this finding. These can help clarify why prices are rising and falling, making it more about the facts of cost than the perception of corporate exploitation.

In addition, recent legislative, actuarial and institutional studies validate that targeted transparency changes the behavioral and regulatory environment of contract renewals. Thematic evidence from legislation captured by FMT News (2026) demonstrated that public complaints about structural price changes drastically diminish when transparency of medical consumable markups is provided in an unbundled way, pointing to the need for transparency on the many moving parts of cost-push inflation.

From an operations perspective, Actuaries Digital (2025) demonstrated how the removal of opaque, non-risk optimization parameters and their replacement by transparent data feeds increases consumer confidence at contract renewal time.

At the end, this is a paradigm shift towards radical clarity that is required by macroeconomic realities, and which is being driven through institutional reporting. Aon (2025) stresses the importance of data transparency as the key to countering consumers' lack of trust in the structural changes and to making understanding the drivers of the global medical trend the main way that the market retains trust.

Institutional Trust and Acceptance of Repricing

Institutional trust is an important mediation factor in reducing consumer resistance in times of high economic volatility. There is vertical trust (trust that the apex state regulator (e.g., Central Banks) would conduct itself fairly in regulating market practices) and horizontal trust (trust that commercial insurance and takaful operators would price their takaful portfolios fairly). Consumers' trust acts as a psychological form of wealth that helps to avoid mass policy lapses when premium adjustments cross historical pricing thresholds. When consumers feel that the provider and the regulator are doing what is good for the people, they are more accepting of rate increases.

A large body of literature exists that shows that institutional, vertical and horizontal trust are important factors to ensure financial and systemic stability during economic volatility. On a macro level, the study of Ben Amor et al. (2024) showed that institutional trust can be seen as a psychological anchor that helps to maintain long-term contractual relations in economically unfavorable conditions and thus acts as a buffer against economic shocks.

Good governance is a key precondition that is actively nurtured through proactive measures, as Bank Negara Malaysia (2024) demonstrated in its ability to sustain systemic trust and provide a floor for financial stability in hyper-inflationary cycles by implementing structural interim relief measures. Additionally, system oversight reinforces the mechanics of trust in the regulatory framework that consumers have in the system. The World Bank (2026) found that strict regulatory oversight and a central claims database strengthen consumer ‘vertical trust’ and help to ensure that the public doesn't backlash against the price changes they need.

At the same time, horizontal trust and collective stability in particular corporate and cultural structures must be promoted to guarantee the market equilibrium. Pricing corrections may often be smoother when firms comply with the regulatory rules on premium smoothing, as demonstrated by empirical evidence presented by Prudential Malaysia (2025b) that compliance with the rules of premium smoothing by the firms increases horizontal trust among consumers during pricing corrections.

This is in alignment with the collaborative practices in the industry, whereby the Malaysian Takaful Association

(2024) found that the level of institutional trust established through a risk-sharing approach, is found to be correlated with the level of public acceptance of rebalancing of the funds. These studies together highlight the importance of ensuring the sustainability of the market by maintaining systemic trust, where regulatory authorities, insurers, and mutual arrangements are all on the same side, consumers' interests are clearly protected, and relief is provided through a structured mechanism.

Health Insurance Literacy and Acceptance of Repricing

Health Insurance Literacy (HIL) is a consumer's mental ability to comprehend, assess and choose health insurance portfolios as well as to understand the workings of risk-sharing mechanisms. A key challenge in emerging markets is that low HIL continues to be a recurring blockage in the achievement of public policies.

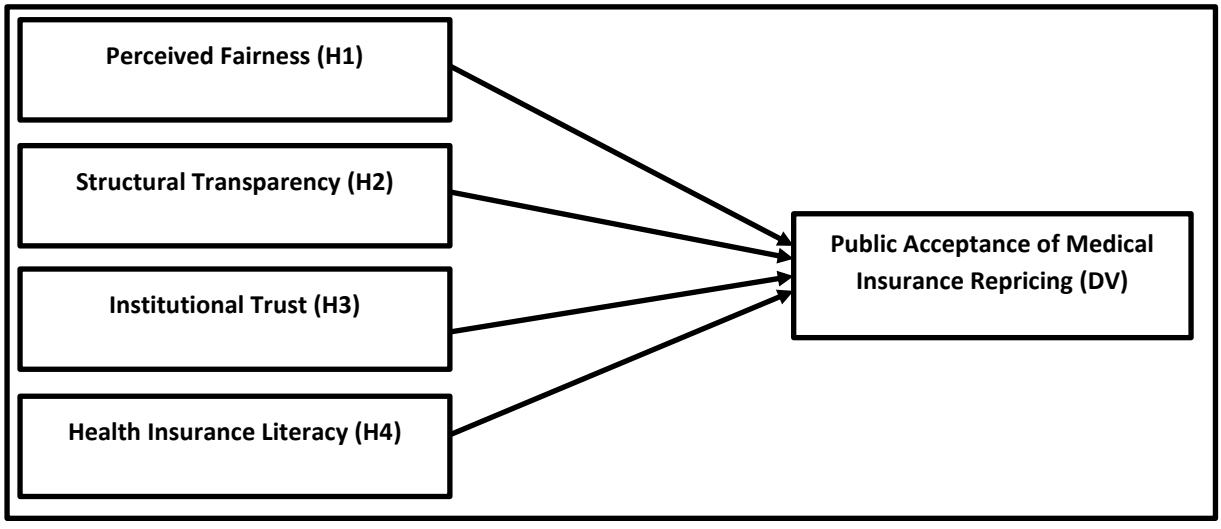
Several recent studies suggest that financial, insurance and health literacy are important factors in reducing consumer resistance to structural price changes. On a basic level, Zhang and Zhao (2024) identified financial and insurance literacy as critical boundary conditions that create a difference in how consumers perceive the fairness of price increases when applying for a service, implying that a customer's ability to understand pricing frameworks has an impact on their perception of equity.

This is corroborated by empirical evidence, MCIS Life (2024) showed that consumers who are more financially capable and comprehend their financial portfolios are less resistant to revised pricing terms. Moreover, this connection directly translates to the implementation of national healthcare financing reforms at a larger scale. The Ministry of Health Malaysia (2023) highlighted that "Increasing public health literacy is fundamental to the effective implementation of the national health financing reforms at a broad scale, thus making literacy a necessary foundation for wider structural reform.

Targeted educational interventions are effective at the operational and structural level of neutralizing consumer friction and cognitive biases. In the corporate environment, WTW (2025) found that there is a lower incidence of employee grievances over co-payment restructurings where health literacy elements are part of corporate wellness programs indicating that proactive education can help ensure a smoother transition to benefits.

This mitigation strategy is especially effective when facing deep-seated consumer biases, as a recent example of public response to repricing risk-pools by the World Bank (2026) demonstrates that financial literacy campaigns can directly reduce consumer pushback on risk-pool repricing through a targeted effort to correct the "savings account misconception" that consumers often have about insurance premiums. Taken together, these studies demonstrate that elevating consumer comprehension across financial and health domains is a highly effective mechanism for ensuring the sustainability of insurance pricing structures.

Figure 1: Conceptual Model of Medical Insurance Repricing Acceptance



H1: Perceived fairness has a significant positive relationship with consumer acceptance of medical insurance repricing.
H2: Structural transparency has a significant positive relationship with consumer acceptance of medical insurance repricing.
H3: Institutional trust has a significant positive relationship with consumer acceptance of medical insurance repricing.
H4: Health insurance literacy has a significant positive relationship with consumer acceptance of medical insurance repricing.

3. Research Methodology

The study was quantitative, cross-sectional, and descriptive survey design, with the aim to examine the effect of Perceived Fairness, Structural Transparency, Institutional Trust, and Health Insurance Literacy (independent variables) on Public Acceptance of Medical Insurance Repricing (dependent variable) in Malaysia. This deductive approach creates an empirical route for capturing consumer behavioral intentions in the context of private health care insurance.

A quantitative, cross-sectional survey design was used in the fast-growing suburban township of Puncak Alam, Selangor which is made up of middle (M40) and upper-middle (T20) class commuters who depend on private healthcare schemes.

Again, utilizing sampling guidelines proposed by Hair et al. (2019), N=100 was determined to have sufficient statistical power (> 0.80) to support a linear regression model based on four predictors with an $\alpha = 0.05$, which is above the minimum recommended by G*Power 3.1 analysis.

Primary data was gathered by using a self-administered questionnaire with 12 items adapted from literature that have been validated that was measured using a 5-point Likert scale from "Strongly Disagree" (1) to "Strongly Agree" (5). All participants were residents of Puncak Alam and had an active insurance policy and strict ethical protocols were observed to ensure that all participants' identities were protected. The 12-item measurement instrument was adapted from validated scales. Cronbach's Alpha ($\alpha > 0.70$) and Composite Reliability (CR > 0.70) were used to check psychometric reliability.

Table 1: Measurement Items, Adaptation Sources and Reliability Analysis

Construct	Item Code	Measurement Statement	Source	Cronbach's α	CR
Acceptance (DV)	ACC1	Willing to accept a premium increase based on genuine cost trends.	Adapted from Ben Amor et al. (2024)	0.842	0.885
	ACC2	Clear breakdown provided makes adjustment acceptable.			
	ACC3	Understanding inflation/risk-pooling mechanisms makes the adjustment acceptable.			
Fairness (IV1)	FAIR1	Premium increase is fair based on individual medical usage.	Adapted from Kahneman et al. (1986); Zhang & Zhao (2024)	0.815	0.868
	FAIR2	Repricing is reasonable considering benefits received.			
	FAIR3	Insurer/operator has justified the premium hike fairly.			
Transparency	TRN1	Insurer explained reasons			

(IV2)		for repricing clearly.	Adapted from		
	TRN2	Informed in advance about premium changes.	Khazanah Research Institute	0.829	0.876
	TRN3	Understand how the new premium was calculated.	(2024)		
Trust (IV3)	TRST1	Operator acts in the best interest of policyholders.			
	TRST2	Trust the operator to manage policy responsibly.	Adapted from Bank Negara Malaysia (2024)	0.867	0.901
	TRST3	Confident operator is honest about pricing decisions.			
Literacy (IV4)	LIT1	Understand basic terms and benefits of a health plan.			
	LIT2	Know how to use health insurance when care is needed.	Adapted from World Bank (2026)	0.854	0.893
	LIT3	Aware of what is covered and excluded under the policy.			

4. Results

The primary objective of this study is to examine the factors affecting Medical Insurance Repricing Public Acceptance among the factors: Perceived Fairness, Structural Transparency, Institutional Trust and Health Literacy for the Public.

Demographic Information of Respondents: A summary of the demographic information of respondents who participated in the study is presented in Table 2.

Table 2: Demographic Profile

Variable	Frequency	Percentage
GENDER		
Males	31	31.0%
Females	69	96.0%
Total	**100**	**100%**
AGE		
21-30 years	71	71.0%
31-40 years	28	28.0%
41-50 years	1	1.0%
Total	**100**	**100%**
EDUCATION		
Diploma	13	13.0%
Degree	79	79.0%
Master / PhD	8	8.0%
Total	**100**	**100%**
MONTHLY HOUSEHOLD INCOME		
Below RM2,500	29	29.0%
RM2,501 – RM4,850	28	28.0%
RM4,851- RM10,970	30	30.0%
Above RM10,971	13	13.0%
Total	**100**	**100**
TYPES OF COVERAGE		
Individual private	55	55.0%
Employer - provided group	22	22.0%

Family or dependent	13	13.0%
Government–subsidized schemes	7	7.0%
Social health protection	3	3.0%
Total	**100**	**100**
DURATION		
Less than 1 year	**16**	16.0%
1-3 years	**26**	26.0%
4-6 years	**33**	33.0%
7-10 years	**15**	15.0%
More than 10 years	**10**	10.0%
Total	**100**	**100**

Descriptive Statistics: Descriptive analysis was used to summarize the data, highlighting the significant factors that influence their acceptance of medical insurance repricing. The results detailing these factors are presented in Tables 3, 4, 5, 6 and 7 below.

Table 3: Mean Score and Standard Deviation for Acceptance of Medical Insurance Repricing

Item	Mean	Std. Dev.
I am willing to accept the premium increase because I trust that the revised pricing genuinely reflects rising healthcare costs and the overall value of my medical benefits.	3.83	1.217
The clear and comprehensive breakdown provided by my insurer regarding why the repricing was necessary makes me more willing to accept the premium adjustment.	3.21	0.962
Because I understand how medical inflation and pool-risk mechanisms impact insurance sustainability, I view this premium repricing as an acceptable adjustment.	3.84	0.973

Table 3 summarizes the descriptive statistics for the consumer acceptance of medical insurance repricing, providing interesting information about consumer attitudes toward medical insurance policies. Generally, the results show that the majority of respondents were willing to accept some premium adjustment, contingent upon their ability to understand what was driving the system. The greatest agreement for this item was regarding the understanding of macroeconomic factors (M=3.84, SD=0.973). This indicates that, if insurance policyholders are able to understand the effect of medical inflation and the effect of pool-risk mechanisms on the sustainability of insurance funds, they would accept the premium repricing as a necessary and acceptable adjustment.

Similarly, people's trust in costs and value (M=3.83, SD=1.217), meaning that they feel prepared to pay a premium for the revised pricing if it is seen as being truly representative of the escalation of healthcare costs, is also high. Compared to their macroeconomic awareness, however, the relatively more volatile standard deviation suggests consumer trust is more polarized or variable than their macroeconomic awareness, suggesting greater differences in their views. However, the lowest mean score (M=3.21, SD=0.962) was given to the item asking about the clarity and comprehensiveness of the breakdown directly provided by the insurers. This is a lower mean, but it is still positive, which indicates a significant lack of communication within the business.

These findings suggest that policyholders have a general, high-level knowledge of medical inflation and risk pooling but are less satisfied with the explanations they receive from their individual insurance companies. The results highlight that systemic acceptance is strongly related to the general market awareness and the overall trust in the system; however, to break the disconnect between the abstract market awareness and the system's acceptance, insurers should implement more transparency and clarity in their communications on price changes.

Table 4: Mean Score and Standard Deviation for Fairness

Item	Mean	Std. Dev.
The premium increase is fair based on my use of medical insurance.	3.47	1.0960
The repricing is reasonable considering the benefits I receive.	3.54	1.1496
I believe the insurer or takaful operator has justified the premium hike fairly.	3.79	1.0473

Table 4 above presents descriptive statistics (mean scores and standard deviations) for each of the items measuring respondent perceptions of insurance premium repricing fairness. Each item was rated on a 5-point Likert scale with higher mean scores representing higher agreement with the item.

Overall, the empirical findings indicate a favourable attitude among respondents towards the fairness of the price changes with the mean scores of all items being well above the midpoint of the scale (3.00).

Interestingly, the highest level of agreement was found for the item relating to corporate transparency and reason, "I believe the insurance company or takaful operator has been justifiable in the premium increase in a fair manner" (*M*=3.79, *SD*=1.0473). This reflects the importance of and the relative acceptance of the operators' reasons behind the increases.

At the same time, respondents moderately agreed that the structural repricing was justified when compared to the benefits they receive (*M*=3.54, *SD*=1.1496) the item "The repricing is reasonable considering the benefits I receive. On the other hand, the lowest mean score of this construct was in relation to individual consumption, "The premium or contribution increase is fair according to my use of the medical insurance" (*M*=3.47, *SD*=1.0960). This slight decline is still positive but indicates a slight shift in the minds of policyholders regarding price increases being more sensitive to personal usage levels than broader institutional reasons.

In terms of data dispersion, the standard deviations in all three dimensions were relatively constant ranging from 1.0473 to 1.1496. This means there is a moderate and reasonable range of consumer perceptions, suggesting that there is a general agreement towards greater acceptance, but some individual experiences and ways of using repricing are causing slight differences in the market in how the fairness of repricing is perceived.

Table 5: Mean Score and Standard Deviation for Transparency

Item	Mean	Std. Dev.
The insurer or takaful operator explained the reasons for repricing clearly.	3.75	1.0952
I was informed in advance about the premium or contribution changes.	3.89	1.1361
I understand how the new premium was calculated.	3.54	1.1757

The descriptive statistics for the items measuring the construct of perceived transparency were also examined, along with perceived fairness. The mean scores and standard deviations for each item within this dimension are shown in Table 5, on a similar 5-point Likert scale.

The descriptive statistics indicate that in general, the respondents had a high perception of transparency of their insurance/takafuls operators, with all items' means above the neutral point of the scale (3.00). There were no significant differences among the sub-constructs except for the sub-construct of tracking advance communication with *M*=3.89, *SD*=1.1361, which earned the highest mean. The result reflects strong compliance with regulators' deadlines for notifications, meaning policyholders will not be caught by surprise with possible structural changes.

In addition, the respondents showed a high level of agreement on the clarity of the corporate communication, with the item "The insurer or takaful operator explained the reasons for repricing clearly" having a mean score of 3.75, *SD*=1.0952. This shows that the message as to why the price increase has happened was effectively pushed through to the consumer market.

The item with the lowest mean score under this construct was "I understand how the new premium was calculated" with a mean of 3.54 and SD of 1.1757. This score represents a net positive consensus and the

percentage drop indicates that there is a technical awareness/consensus gap in communication. That is, policyholders understand that the pricing is increasing and why it is needed, but they are not as well aware of the actuarial details behind the new pricing.

There is a slightly larger range of standard deviations for this construct, from 1.0952 to 1.1757. The item that had the highest variance (*SD*=1.1757) was the item on calculation comprehension. This means that the levels of consumer insurance literacy are very unevenly distributed, with some consumers being much worse than others at understanding financial calculations.

Table 6: Mean Score and Standard Deviation for Trust

Item	Mean	Std. Dev.
I believe the insurer or takaful operator acts in the best interest of its policyholders.	4.07	0.9667
I trust the insurer/takaful operator to manage my policy responsibly.	4.14	0.8648
I feel confident that the insurer or takaful operator is honest about pricing decisions.	3.90	1.0299

Then the descriptive statistics of the items that measured consumer trust were analyzed after the fair and transparent analysis. The mean scores and standard deviations for this construct are given in Table 6 evaluated on a 5-point Likert scale.

The empirical findings revealed that the overall mean scores of the insurance and takaful operators were in the high category (*M*>3.90) and in the 'agree' range of the scale. The item that got the highest average score was operational capability and fiduciary duty: "I trust the insurer or takaful operator to manage my policy responsibly" (*M*=4.14, *SD*=0.8648). This is a good indicator of the level of institutional confidence in the operators' key competency and the reliability of the administration.

Similarly, those who believed that the motivations were consumer-centric were strong with the mean value of *M*=4.07, *SD*=0.9667 for the item 'I believe the insurer or takaful operator acts in the best interest of the policyholder'. This means that a price increase may have some financial friction, but there is a general trust in the goodwill of providers by the policyholders.

The item with the lowest mean score in this construct was the item that specifically relates trust to pricing integrity, namely, "I feel confident that the insurer/taklaful operator is honest about pricing decisions" (*M*=3.90, *SD*=1.0299). Still a fairly high degree of agreement, but also the lowest mean and highest standard deviation (*SD*=1.0299) with a critical nuanced takeaway. Where consumers have some trust in the operators to take responsibility for operating their policies on a macro level, they are more skeptical and diverse on the macro level in their views and opinions on the honesty of the repricing and pricing mechanisms.

Table 7: Mean Score and Standard Deviation for Health Insurance or Takaful Literacy

Item	Mean	Std. Dev.
I understand the basic terms and benefits of my health insurance or takaful plan.	4.35	0.8087
I know how to use my health insurance or takaful when I need medical care.	4.20	0.8762
I am aware of what is covered and not covered under my policy.	4.25	0.8919

The empirical findings suggest very high self-reported literacy levels for the respondents with all mean scores well above 4.00. Fundamental comprehension: "I understand the basic terms and benefits of my health insurance or takaful plan" received the highest mean: 4.35 (*SD*=0.8087) in this construct. Such a high level of agreement indicates that consumers have a high degree of confidence in their understanding of basic policy jargon and underlying contract features.

Likewise, there was a high level of awareness of policy parameters, with a mean score of M=4.25 and SD=0.8919 on the item "I am aware of what is covered and not covered under my policy". This means that the sample

population is overall very familiar with the policy exclusions and inclusions which can be crucial in the process of claims. This means that the sample population is generally very familiar with the policy inclusions and exclusions which can be crucial in the claims process.

The lowest mean score within the construct was for the item tracking practical application, "I know how to use my health insurance or takaful when I need medical care" (M=4.20, SD=0.8762), but it is still quite high. Such an edge gap suggests that although policyholders have a good understanding of their plans, a slightly lower percentage is confident in performing the actual medical plan procedures.

Significantly, the standard deviation of all items in Table 7 is the lowest for all the analyzed constructs ranging from 0.8087 to 0.8919. The data points are concentrated, indicating a high level of agreement and little spread among the respondents, which means that the level of health insurance or takaful literacy is generally strong among the sampled population.

Inferential Results and Hypothesis Testing.

Multiple Linear Regression analysis has been carried out for the evaluation of proposed hypotheses (H1 - H4). Variance Inflation Factor (VIF) was used as a test for multicollinearity, with values of all independent variables being much lower than 5.0 (ranging between 1.34 and 2.12), which showed no serious multicollinearity.

Table 8: Multiple Linear Regression Analysis Results (DV = Repricing Acceptance)

Predictor Variable	Unstandardized *B*	Std. Error	Standardized *β*	*t* - value	*p* - value	VIF	Hypothesis Result
(Constant)	0.412	0.281	-	1.466	0.146	-	-
Fairness (H1)	0.324	0.088	0.312	3.682	0.001	1.62	Supported
Transparency (H2)	0.185	0.079	0.194	2.341	0.021	1.84	Supported
Trust (H3)	0.298	0.091	0.285	3.274	0.001	1.95	Supported
Literacy (H4)	0.162	0.074	0.171	2.189	0.031	1.41	Supported

Note: Model R^2 = 0.548, Adjusted R^2 = 0.529, F (4,95) = 28.78, p < 0.001.

The regression model explains 54.8% of the variation in consumer repricing acceptance (R^2=0.548). Institutional Trust (β=0.285, p=0.001) and Perceived Fairness (β=0.312, p<0.001) were the next strongest predictors, followed by Transparency (β=0.194, p=0.021) and Health Insurance Literacy (β=0.171, p=0.031). Therefore, H1, H2, H3 and H4 are supported statistically.

5. Discussion and Recommendations

This study explored behavioral and structural factors that influence medical insurance policyholders in Puncak Alam, Selangor to accept repricing. The empirical findings offer valuable insights into consumer behavioural economics in a developing economy where the pressure of medical hyper-inflation has not been seen before and mainly on the importance of Fairness, Transparency, Trust and Health Insurance Literacy.

Perceived Fairness and Acceptance of Medical Insurance Repricing (H1)

Overall, the results of the descriptive analysis of perceived fairness are positive and the mean scores were higher than the neutral score of 3.00. In particular, the highest level of agreement was found with corporate reasons for adjustments (M=3.79, SD=1.0473). This is indicative of a cognitive consistency with the Dual Entitlement Theory, which suggests that consumers become more tolerant of price increases if they see the increase as resulting from macro-economic cost-push inflation, rather than pure profit-maximizing by the company. This is consistent with the results of Ben Amor et al. (2024) and Zhang & Zhao (2024) that suggest a perception of equity and psychological anchors are the factors that determine whether someone will accept a change in the contractual rate.

The lowest mean score in this construct was found for fairness relative to individual consumption (M=3.47, SD=1.0960). This marginal decline underscores the "risk-pooling misconception," which refers to a lower-utilization policyholder who believes that his/her good health will protect him/her from the market

adjustments that the market imposes on the policyholders collectively. The slight frictions are noted here because, as per the World Bank (2026), premium shocks that are not adjusted and hence do not consider the individual risk are in violation of distributive justice.

Apart from that, the perceived fairness's strong impact (β=0.312) is consistent with those found by Ben Amor et al. (2024), and Zhang & Zhao (2024). When price hikes are thought to stem from outside factors, rather than increased corporate profits, the consumer will endure them.

Structural Transparency and Acceptance of Medical Insurance Repricing (H2)

The transparency in corporate communication received a very positive net evaluation. For proactive alerts, operators achieved satisfactory results in terms of regulatory baseline benchmarks where the highest mean (M=3.89) was obtained for advance notification within the construct (SD=1.1361). This highlights regulatory notification parameters compliance. In addition, price rationales have been clearly explained *(*M=3.75) which means that strategic organizational messages have been conveyed successfully.

However, the lowest mean score (M=3.54, SD=1.1757) and the highest variance were found for functional understanding of the new premium. This suggests an uneven model where policyholders know that the increase is happening and why, but they are structurally disconnected from the technical actuarial aspects of the recalculations. This aligns with the literature by Khazanah Research Institute (2024), which attributes public objections to the informational opacity of unbundled calculations and by Prudential Malaysia (2025b) which attributes public objections to opaque private hospital billing structures.

In addition, the transparent structure (β=0.194) minimizes cognitive load as a result of which the price shock is understood as structured economic. This corroborates the Khazanah Research Institute's (2024) theoretical framework.

Trust and Acceptance of Medical Insurance Repricing (H3)

Institutional trust is a significant buffer in economic corrections, with the highest cumulative measures in this study (M>3.90). The operational capacity and responsibility for managing policies was strongly affirmed by respondents (M=4.14, SD=0.8648). They also had a strong belief in operators doing what was best for them (M=4.07). It's a fundamental courtesy that suggests no broader institutional hostility from consumers but rather some local economic grievance.

Importantly, the mean (M=3.90, SD=1.0299) and the highest variance were for trust specifically related to pricing integrity. Policyholders have an innate distrust of the validity of pricing decisions. To boost both vertical and horizontal trust, state measures need to be visible such as premium-smoothing mechanisms and claims databases, to demonstrate that price increases are warranted by a macroeconomic reality and not by corporate opportunism as noted by Bank Negara Malaysia (2024) and the World Bank (2026).

Furthermore, institutional trust (β=0.285) is also found to be an important buffer during economic shocks and is consistent with the findings of Bank Negara Malaysia (2024) and the World Bank (2026). Systematic lapse rates reduce as policyholders trust the policy due to regulatory monitoring.

Health Insurance Literacy and Acceptance of Medical Insurance Repricing (H4)

Health Insurance Literacy (HIL) displayed exceptionally robust self-reported metrics across the surveyed cohort, with all item means surpassing the 4.00 threshold and demonstrating the lowest standard deviations (0.8087 to 0.8919). Policyholders expressed high confidence in understanding basic terms and benefits (M=4.35) and policy exclusions (M=4.25). This tight data cluster signifies a highly educated demographic, composed mainly of the suburban M40 and T20 income brackets in Puncak Alam, who actively interact with private health insurance frameworks.

Practical application regarding hospital execution yielded a slightly lower mean (M=4.20). This slight deviation indicates that despite possessing high conceptual knowledge, consumers encounter operational hurdles when navigating real-world medical facilities. According to Cognitive Load Theory, when consumers lack structural breakdown frameworks for premium hikes, they default to negative heuristics. High HIL, as substantiated by

MCIS Life (2024) and the Ministry of Health Malaysia (2023), acts as a critical prerequisite that transforms raw price shock into rational economic comprehension.

This result aligns with the findings of Ruslan and Mohd Rasid (2024), who demonstrated that knowledge, promotional efforts, and perceived benefits significantly dictate vehicle owners' decisions to extend their special perils coverage. This is further supported by Mohamad Basir et al. (2025), who similarly indicated that knowledge and promotion, alongside consumer attitude, play a critical role in influencing air travelers' awareness regarding travel insurance. Furthermore, these findings complement a recent study by Ruslan et al. (2025) on property owners in Puncak Alam, Selangor, which revealed that homeowners' insurance purchase intentions are significantly and positively associated with insurance awareness, perceived product adequacy, and household income. Taken together, these studies underscore that across various insurance sectors, such as motor, travel, or property, consumer knowledge, awareness, and product perception remain the foundational drivers of adoption behavior.

Similarly, increases in consumer literacy (β=0.171) reduce cognitive burden, as consumer literacy has a direct impact on consumer understanding, which is consistent with the theoretical aspects outlined by Khazanah Research Institute (2024).

Based on the empirical findings, the following three interconnected strategic interventions are recommended for policymakers, regulators, and insurance operators:

Transition from Opaque Communication to Actuarial Demystification
Insurance operators should break the "black-box" underwriting pattern as there is a gap between awareness of repricing and technical understanding of premium calculations (M=3.54). It is recommended that operators develop co-created, user-friendly digital calculators that allow policyholders to input individual metrics and see exactly how claims inflation alters their risk pools. Furthermore, following the recommendations of the Public Accounts Committee (PAC) and Khazanah Research Institute (2024), regulators must enforce unbundled, itemized transparency on private hospital billings to neutralize artificial markups on medical consumables.

Accelerate Structured Cost-Sharing and Standardized Base Plans
To reconcile the tension between low individual utilization and compounding premium hikes (M=3.47), the industry must pivot away from traditional individual riders toward sustainable cost-sharing variations. Policymakers should accelerate the deployment of mandatory co-payment product variations and the upcoming 2027 standardized "base" medical plans proposed by the Ministry of Health's Health White Paper (2023). Eliminating luxury, unbundled medical charges will directly restore the consumer's sense of distributive justice and minimize moral hazards.

Institutionalize Long-Term Regulatory Premium-Smoothing Frameworks
In order to protect pricing integrity and mitigate the high variance in consumer trust regarding pricing honesty (M=3.90, SD=1.0299), Bank Negara Malaysia should institutionalize its interim relief measures into permanent frameworks. Moving away from cyclically delayed, compounding premium shocks (which historically ranged between 40% and 70%), BNM must mandate that future adjustments are structurally staggered over fixed multi-year periods. Ensuring that annual adjustments remain below a predictable threshold anchors systemic trust, prevents mass policy lapses, and shields vulnerable demographics over the long term.

Conclusion
The study was able to successfully assess the behavioral drivers influencing the acceptance of medical insurance repricing in the Malaysian emerging marketplace, specifically the suburban township of Puncak Alam, Selangor. The empirical evidence, backed by an extensive sample consistent with Roscoe's multivariate model, confirms that overall confidence in the foundations of institutional trust and confidence in their own health insurance literacy remain strong, but there are several points of consumer friction: pricing honesty and premium calculation. Cost drivers in the macro-environment are rationalized by policyholders while they tend to be skeptical of price increases when they do not see these costs reflected in their own use or when the associated private hospital charges are difficult to understand.

This research theoretically fills an important gap in the empirical literature in ASEAN behavioral health economics, as it embeds the concepts of Equity Theory, Dual Entitlement Theory and Cognitive Load Theory in a healthcare system that is predominantly individual insurance rider-based and not reliant on the Western employer-based system. The research from a practical point of view highlights the need for premium adjustments not to be made just mathematically, but sustainably as well as the need to consider transparency and structured regulatory anchors and the breakdown of actuarial setting.

Lastly, a balance between the solvency of institutions and consumer protection requires active involvement, collaboration, and partnership between the commercial operators and the state regulators. Structured premium-smoothing mechanisms expand standardized cost-sharing portfolios and auditing of healthcare billing pipelines are key elements to leveling the market. The measures will ensure the sustainability and availability of private healthcare protection amongst the Malaysian masses.

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Assessing Students' Conceptual Understanding of an Islamic Financial System Course Using the Rasch Wright Map

Mohd Rahim Khamis[1], *Mohd Faizal Kamarudin[1], Nur Afizah Muhammad Ariffin[1], Mohd Faizan Mohd Afandi[2]
[1]Department of Economics and Financial Studies, Universiti Teknologi MARA, Puncak Alam, Selangor, Malaysia
[2]Assistant Vice President, Al-Rajhi Bank, Malaysia
Email: *mfk@uitm.edu.my
Corresponding Author: Mohd Faizal Kamarudin

Abstract: The rapid growth of Islamic finance has increased the need for effective assessment methods that accurately evaluate students' conceptual understanding of Islamic financial principles beyond the traditional score-based approaches. This study examines the application of the Rasch Wright Map in assessing students' conceptual understanding of the Islamic financial system course. A quantitative research design was employed involving 84 first-year Islamic Banking students at Universiti Teknologi MARA (UiTM). Data were collected using a nine-item Exit Survey Test (EST) designed to measure students' general understanding and practical knowledge of the Islamic financial system. Rasch Model analysis using WINSTEPS 3.71.0.1 demonstrated strong psychometric properties, with item reliability recorded at +0.86 and person reliability at +0.68. The Wright Map provided a visual representation of students' conceptual mastery by simultaneously mapping person ability and item difficulty along a single logit scale. The findings revealed that 61% of the students demonstrated good conceptual understanding and could apply their knowledge in practical contexts. However, several items related to Islamic capital markets, Islamic money markets, takaful, and retakaful were identified as challenging. The study concludes that the Rasch Wright Map is an effective psychometric tool for evaluating conceptual understanding in Islamic finance education and offers valuable implications for curriculum enhancement and instructional improvement.

Keywords: *Conceptual understanding, Islamic Financial System, Rasch Model, Wright Map*

1. Introduction

The global expansion of Islamic finance has transformed it from a niche sector into a significant component of the international economic landscape. Yet, this growth has revealed a critical need for a deeper conceptual understanding of its unique ethical and legal foundations. Governed by Shariah principles—such as the prohibition of *Riba* (interest), *Gharar* (uncertainty), and *Maysir* (gambling)—the system requires practitioners and students to master complex risk-sharing mechanisms and contract structures that differ fundamentally from conventional finance (Khamis & Hashim, 2025). This development has increased the demand for graduates who possess not only theoretical knowledge but also a comprehensive conceptual understanding of Islamic financial principles and their practical applications. Consequently, higher education institutions play a critical role in preparing future professionals who can operate effectively within the increasingly sophisticated Islamic finance industry.

Despite the growing importance of Islamic finance education, assessing students' conceptual understanding remains a significant challenge. Many higher education institutions still primarily rely on traditional exams and raw-score evaluations for their assessment procedures. As a result, educators are not given enough diagnostic data to determine which areas need more instructional intervention. These restrictions impede ongoing teaching and learning improvement and lessen the efficacy of curriculum evaluation. Hence, a significant issue persists in how this understanding is measured; traditional assessment methods typically rely on raw scores, which fail to distinguish between an individual's actual competency and the inherent difficulty of the questions. This "measurement gap" often results in an inaccurate profile of learner ability, as standard tests cannot pinpoint exactly which *Shariah* concepts, such as *Murabahah* or *Sukuk*, act as the primary cognitive hurdles for learners (Akbar et al., 2023).

This study utilizes the Rasch Measurement Model and its central diagnostic tool, the Wright Map, to provide a more rigorous and linear evaluation of conceptual mastery. The Wright Map allows for the simultaneous plotting of person ability and item difficulty on a single logit scale, creating a visual "competence continuum"

that reveals how well the assessment instrument aligns with the actual knowledge level of the respondents (Boone, 2016). The primary aim of this study is to assess Islamic banking students' understanding of the fundamental concepts underpinning the Islamic financial system.

Using a Rasch-based Exit Survey Test (EST), this study generates empirical evidence on students' mastery of specific curriculum areas while identifying concepts that continue to pose learning challenges. By diagnosing these gaps and aligning items with learner ability, the study aims to enhance the validity of Islamic financial education and provide empirical evidence to guide more effective curriculum development and professional training (Khamis & Hashim, 2025).

2. Literature Review

The development of Islamic finance education has not always been accompanied by equivalent growth in students' conceptual understanding. Although students generally demonstrate positive attitudes toward Shariah-compliant banking, empirical studies indicate that their functional literacy in Islamic finance remains relatively limited compared to conventional finance (Bley & Kuehn, 2009). This literacy gap is largely attributed to the complexity of Arabic terminology and the lack of standardized curricula integrating Islamic jurisprudence (*Fiqh Muamalah*) with modern financial practices.

Bley and Kuehn (2009) indicate that student understanding of Islamic finance is often lower than their understanding of conventional systems. For example, research among university students in the UAE found that while knowledge of conventional banking terms was relatively high, Islamic banking terminology was poorly understood. This is because some factors contribute to this situation, such as student understanding of Islamic financial systems is multifaceted, involving a complex interplay between personal values and academic exposure. While literature identifies religious commitment as the primary driver for choosing Islamic banking services, it is paradoxically not a reliable predictor of technical knowledge; students may favor the system ideologically without grasping its operational mechanics (Bley & Kuehn, 2009). A significant cognitive barrier is the specialized Arabic terminology—such as *Mudarabah* (profit-sharing) and *Gharar* (uncertainty)—which often remains inaccessible even to students in Muslim-majority regions due to its dense, legalistic nature (Yuslem et al., 2023). Furthermore, while students majoring in finance naturally outperform their peers in other disciplines, a pervasive "literacy gap" persists across the academic spectrum, suggesting that current pedagogical approaches are not yet sufficient to achieve broad-based proficiency (Bley & Kuehn, 2009).

Recent empirical evidence further highlights this educational deficit. Saputra and Rahmatia (2021) reported that the Islamic financial literacy index among students in Indonesia was only 9.14%, significantly lower than conventional financial literacy levels. According to Yuslem et al. (2023), deficiencies in foundational Islamic financial knowledge and religious-financial belief systems remain the primary challenges in Islamic financial literacy.

Despite the growing interest in Islamic finance, research into effective assessment methodologies for evaluating conceptual understanding remains relatively nascent (McGregor & Alghamdi, 2024). Khan and Watson (2003) stated that students frequently find abstract Islamic concepts difficult to understand, particularly when the curriculum incorporates normative frameworks like those found in Islamic economics and finance. Effectively evaluating conceptual understanding is therefore essential in Islamic education, especially in universities where Islamic finance and economics are becoming more popular (Dusuki, 2008).

There are still few standardized and diagnostic evaluation instruments available, even with the expansion of Islamic finance education. The majority of assessments currently in use mainly rely on summative techniques, such as assignments, final exams, and midterms, without sufficiently gauging how well students have internalized the underlying ideas. Moreover, traditional test construction often lacks psychometric validation, thereby limiting the reliability and interpretability of assessment outcomes.

While the evaluation of students' conceptual understanding has been thoroughly examined in the fields of science and engineering education, Islamic Finance has not received as much attention. The capacity to create mental models, synthesize information, and apply concepts to novel situations are all components of

conceptual understanding, which extends beyond factual recall (Smith, 2005). Given the ethical and axiological pillars that support the field, such comprehension is essential in the context of Islamic finance.

Consequently, while various scholars have developed instruments to gauge Islamic financial literacy using multi-item scales, many existing methods rely solely on raw scores, such as true/false questions and multi-item scales, to capture various facets of Islamic finance (Ahmad et al., 2020). Therefore, Nawi et al. (2018) mentioned some methods to measure understanding by just giving points for correct answers in questionnaires and then classifying literacy levels as low, medium, or high. This is not the best method to assess conceptual understanding among students of the Islamic finance aspect. This is because the level of understanding is just based on total marks received by asking questions in a questionnaire. Each correct answer earns points, and the total score is used to determine the student's literacy level. Based on the score achieved, the student may be classified as having low, medium, or high literacy. This approach is insufficient for assessing true conceptual understanding, as it merely classifies literacy levels (low, medium, or high) based on total points without accounting for the relationship between item difficulty and student ability.

Conceptual understanding goes beyond the simple recall of factual knowledge or procedural execution; it represents a learner's ability to organize operational knowledge into coherent mental models, grasp underlying principles, and transfer these frameworks to novel contexts (Smith, 2005). In the domain of Islamic finance education, true conceptual mastery requires students to comprehend complex Shariah logic, such as risk-sharing structures and ethical prohibitions (e.g., Riba, Gharar), rather than merely memorizing Arabic terminology or formulas. Traditional raw-score evaluations treat assessment items as equal additions to a cumulative total, masking whether a student possesses a coherent conceptual framework or merely guessed easy factual questions. Measuring conceptual understanding, therefore, requires a psychometric construct that can order learning concepts hierarchically along a continuum of cognitive difficulty, enabling educators to observe where a student's mental model falters. This structural necessity makes the Rasch Measurement Model particularly suitable. This is because the Rasch Measurement Model offers a more sophisticated approach to educational assessment. The model assumes that the probability of a correct response depends on the interaction between person ability and item difficulty (Linacre, 1999). The Wright Map visually represents this interaction by placing persons and items on a single continuum, thereby allowing researchers to identify easy and difficult items as well as high- and low-performing students (Kay, Bundy, & Clemson, 2008).

Previous studies have demonstrated the usefulness of the Rasch Model in educational assessment. Abdullah, Noranee, and Khamis (2017) applied the Rasch Wright Map to assess conceptual understanding in electricity studies and found that the approach effectively differentiated students' levels of understanding. Similarly, Khamis and Hashim (2025) demonstrated the applicability of the Rasch Model in assessing conceptual understanding in Islamic economics education. The study found that the Rasch Wright map can improve the evaluation process and make it possible to assess student learning in a more complex and insightful way. This is because the Wright map can classify students into several categories based on their ability and understanding. The study showed that the Rasch Measurement model can be applied in various scope studies.

By using the Rasch Wright Map in an Exit Survey Test administered to Islamic banking students, this study extends the application of Rasch measurement to Islamic financial system education by examining students' conceptual understanding through a psychometrically validated assessment instrument.

3. Research Methodology

This study employed a quantitative research design to assess students' conceptual understanding of the Islamic Financial System course using the Rasch Measurement Model. The Rasch Measurement Model was selected as it provides interval-level measurement by transforming ordinal responses into logit measures, enabling more accurate interpretation than conventional raw-score analysis (Bond & Fox, 2015; Linacre, 1999). The study involved 84 first-year undergraduate students enrolled in the Islamic Banking program at Universiti Teknologi MARA (UiTM). The use of a single cohort was appropriate because the study focused specifically on assessing students' conceptual understanding of the Islamic Financial System course at the same stage of academic exposure and within a common curriculum context. Focusing on a single cohort also helped ensure greater consistency in terms of course content, learning outcomes, and instructional exposure, thereby allowing the

Rasch analysis to provide a more focused assessment of students' conceptual understanding. Data were collected using the Exit Survey Test (EST), consisting of nine assessment items designed to measure students' conceptual understanding of the Islamic Financial System course. The assessment items were developed based on the official course learning outcomes and course syllabus to ensure alignment between the instrument and the intended learning objectives. The data were analyzed using WINSTEPS version 3.71.0.1. Respondents were selected through a simple random sampling technique to minimize selection bias and provide an unbiased representation of the student population.

The EST instrument consisted of two sections:

Section 1: General Understanding of Islamic Financial System (Items 1–3)
Section 2: Practical Knowledge of Islamic Financial System (Items 4–9)

Rasch Measurement Model

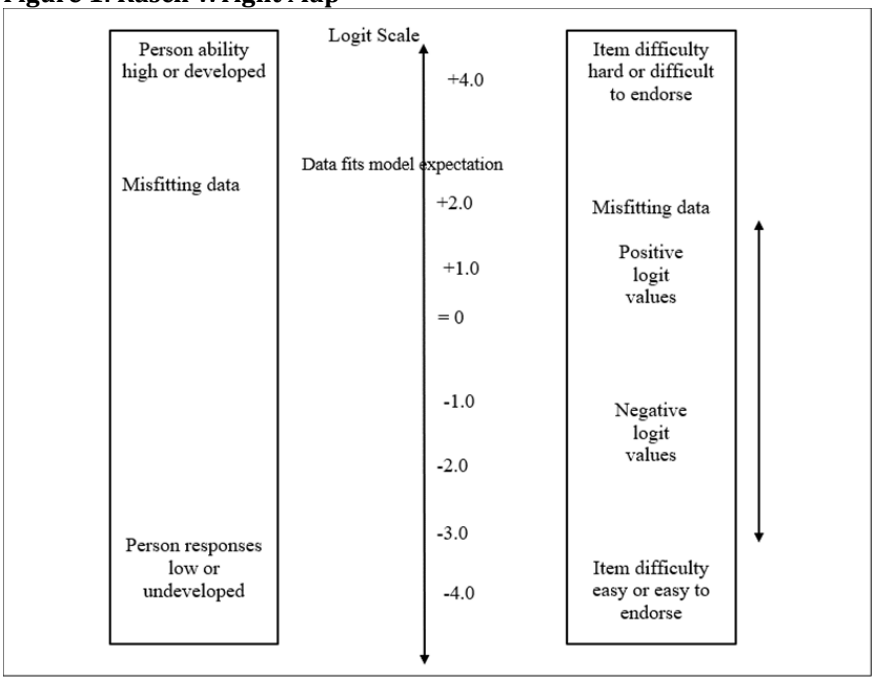
Based on a shared latent characteristic, the Rasch Measurement Model illustrates the connection between a person and an object. It can forecast the probability that a person with a particular ability will correctly answer a question with a particular degree of difficulty. The difference between an individual's ability and the item's difficulty determines the likelihood of success (Bond & Fox, 2015). Two essential theorems form the basis of the Rasch Measurement Model:

- An easier question is more likely to be answered correctly by everyone, and
- A more capable person is more likely to answer all of the questions correctly.

To put it another way, the Rasch Model assumes that an individual's ability determines the item difficulty estimates, whereas the item difficulty is the attribute that influences the individual's responses (Linacre, 1999). A common scale (logit) could be used to predict a person's relationship with an item. Both the person and item positions can be charted using WINSTEPS version 3.71.0.1, the software used in the Rasch Model.

Rasch modelling transforms ordinal scores into linear measures, thereby enabling a more precise interpretation of respondents' performance along a common measurement scale (Sick, 2009). In this framework, persons and items are positioned along a continuum that reflects the interaction between respondent ability and item difficulty. As illustrated in the Wright Map, items are arranged on one side according to their level of difficulty, while respondents are positioned on the other side based on their estimated level of competency (Kay, Bundy, & Clemson, 2008; Jacobs et al., 2014). The Wright Map presented in Figure 1 simultaneously displays person ability and item difficulty on a single logit scale, forming a visual representation of a competence continuum. Items located at the upper end of the map indicate greater difficulty, whereas items positioned at the lower end represent concepts that are easier for respondents to endorse or answer correctly. Conversely, respondents positioned higher on the map demonstrate stronger competency in relation to the measured constructs. In the context of assessing conceptual knowledge in the Islamic Financial System course, the Rasch Wright Map provides a useful diagnostic tool for identifying areas of student mastery as well as concepts that require further instructional reinforcement.

Figure 1: Rasch Wright Map



Source: Bond and Fox (2015)

4. Results

An appraisal of the data fit was conducted to evaluate the extent to which students' responses to the Exit Survey Test (EST) were consistent across all assessment items, thereby determining the overall quality and reliability of the instrument (Smith, 2005). Table 1 presents the summary statistics of the Rasch analysis based on responses from 84 first-year Islamic Banking students to the nine-item EST. The findings indicate that the instrument demonstrated satisfactory psychometric properties for assessing students' conceptual understanding of the Islamic Financial System course.

As presented in Table 1, the EST achieved an item reliability of 0.86**,** which is classified as very good according to Fisher (2007). The index describes the assessment task as being able to discriminate between students' abilities and the difficulty of the assessment task for understanding the conceptual understanding of an Islamic Financial System course. While, the person reliability was 0.68, representing a good level of reliability, suggesting that the measurement was capable of distinguishing students with different levels of conceptual understanding of Islamic Financial System and that they were consistent in their responses.

In addition, the Cronbach's Alpha (KR-20) value of 0.70 indicates acceptable internal consistency, demonstrating that the items consistently measured the same underlying construct. According to Azrilah (2009), a reliability coefficient of 0.70 suggests that respondents would exhibit relatively stable ability estimates if assessed using another instrument measuring the same construct. Collectively, these reliability indices confirm that the EST is a psychometrically sound instrument capable of differentiating students according to their conceptual understanding of the Islamic Financial System. The findings also support the suitability of the instrument for subsequent Wright Map analysis, as the reliability values indicate sufficient measurement precision to interpret both person ability and item difficulty with confidence.

Table 1: Summary Statistics

SUMMARY OF 84 MEASURED Person

	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	38.5	9.0	58.27	6.04	.99	-.04	.99	-.04
SD	3.2	.0	10.83	.75	.42	1.15	.43	1.14
MAX.	44.0	9.0	83.72	10.53	2.08	2.16	2.06	2.14
MIN.	29.0	9.0	24.30	5.45	.11	-3.71	.11	-3.69

REAL RMSE 6.54 TRUE SD 8.63 SEPARATION 1.32 Person RELIABILITY .64
MODEL RMSE 6.09 TRUE SD 8.96 SEPARATION 1.47 Person RELIABILITY .68
S.E. OF Person MEAN = 1.19

Person RAW SCORE-TO-MEASURE CORRELATION = .99
CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .70 SEM = 1.79
STANDARDIZED (50 ITEM) RELIABILITY = .92

SUMMARY OF 9 MEASURED Item

	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	359.3	84.0	50.00	1.95	.98	-.15	.99	.02
SD	13.6	.0	5.30	.11	.20	1.46	.17	1.13
MAX.	382.0	84.0	56.75	2.16	1.27	1.88	1.30	1.92
MIN.	341.0	84.0	41.03	1.86	.67	-2.36	.73	-1.59

REAL RMSE 2.03 TRUE SD 4.90 SEPARATION 2.41 Item RELIABILITY .85
MODEL RMSE 1.96 TRUE SD 4.93 SEPARATION 2.52 Item RELIABILITY .86
S.E. OF Item MEAN = 1.87

Item Fit

The analysis to identify item fit includes three indicators such as point measure correlation value (PtMea Corr), mean square (MNSQ), and Z-standardized (ZSTD). According to Azrilah (2011), there are three criteria to be considered in examining the outfit data. The item is considered to be a misfit with the model if the point measure correlation (PtMea Corr) is larger than 0.4 and less than 0.85 (0.4 <PtMea Corr < 0.85), the outfit mean square (MNSQ) is larger than 0.5 and less than 1.5 (0.5<MNSQ<1.5), and the outfit Z-standard (ZSTD) is larger than -2 and less than +2. The three criteria must be fulfilled in identifying the outfit or outliers in the data. Hence, the item fit as shown in Table 2, revealed that all 9 items were constructed with a positive value of the point measure correlation coefficient (PtMea Corr), indicating that all items measured were in the same direction in the development of the construct. For item misfit, none of the 12 items were identified as misfits, as they did not fulfil the three criteria of misfit responses. This indicated that all the respondents' responses fit with the Rasch Measurement Model.

Table 2: Item Misfit

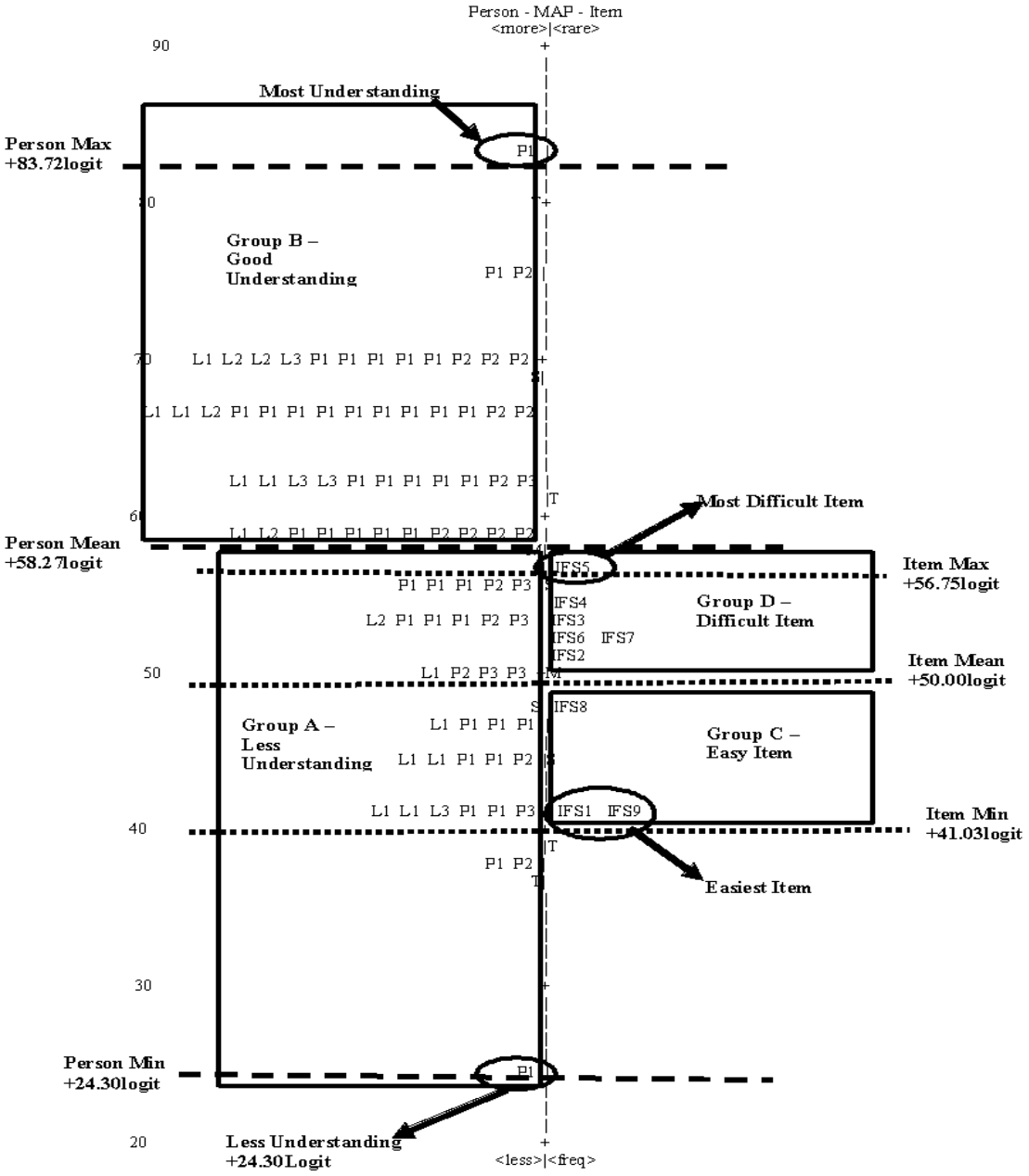
Item STATISTICS: MISFIT ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	JMLE MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
8	366	84	47.75	1.97	1.27	1.88	1.30	1.92	A .41	.54	53.6	61.1	IFS8
4	348	84	54.32	1.87	1.24	1.75	1.21	1.49	B .57	.54	47.6	56.1	IFS4
7	355	84	51.84	1.90	1.11	.82	1.09	.66	C .46	.54	51.2	57.9	IFS7
5	341	84	56.75	1.86	1.08	.61	1.07	.56	D .52	.54	53.6	55.7	IFS5
2	356	84	51.48	1.90	.95	-.37	.94	-.40	E .51	.54	56.0	58.1	IFS2
6	353	84	52.55	1.89	.91	-.64	.91	-.63	d .57	.54	65.5	56.0	IFS6
3	351	84	53.26	1.88	.89	-.85	.87	-.94	c .65	.54	56.0	56.1	IFS3
9	382	84	41.03	2.16	.69	-2.20	.83	-.93	b .56	.52	75.0	68.6	IFS9
1	382	84	41.03	2.16	.67	-2.36	.73	-1.59	a .63	.52	75.0	68.6	IFS1
MEAN	359.3	84.0	50.00	1.95	.98	-.15	.99	.02			59.3	59.8	
P.SD	13.6	.0	5.30	.11	.20	1.46	.17	1.13			9.6	5.0	

Student performance in EST according to the Wright Map

In order to evaluate the conceptual understanding of students of the Islamic financial system, it can be shown through the Rasch Wright Map as Figure 1 below. From the table 1 shows that the mean item was at +50.00logit and the mean person was at +58.27logit. The table also shows that the person's maximum value was +83.72logit, and the minimum was +24.30logit, while the maximum item value was +56.75logit, and the minimum value was +41.03logit. Since the mean person value is positive, it can be confidently said that the 9 items in EST were not too challenging for these respondents, since the mean value for the items is slightly lower than the mean value for the person. By observing the items on the right of the map and taking note that the items above the mean value are the most difficult ones, it can be said that the 9 items can be categorized as easy and difficult based on their location on the map.

Figure 2: Wright Map



As stated in Figure 2, items can be categorized into two categories: easy and difficult items, while persons can also be categorized into two groups: good understanding and less understanding. The locations for easy items are located below the item mean value, while difficult items are located above the item mean value. Meanwhile, the location for good understanding is located above the person mean value, and less understanding is below the person mean value.

Easy Items

- 3 items in **group C** (**IFS1, IFS8 and IFS9),** which are located below the mean value, are the easy items for the students to endorse. This is an indication that the majority of the students had no difficulty in understanding the concept and practical knowledge of the Islamic financial system.
- Item **IFS1,** which is an item dealing with understanding the concept of the Islamic financial system became the easiest item for the students to endorse. This shows that the students had no problem explaining the function of the Islamic financial system. This is not surprising because students already have knowledge related to the concept of the financial system that has been studied previously.
- Items **IFS8 and IFS9** are from the section on practical knowledge of the Islamic financial system. **IFS9 is one** of the easiest items for the students to endorse. This is because this section describes the importance of instruments in the Islamic financial system and the challenges and opportunities faced by the Islamic financial system.

Difficult Items

- 6 items in **group D** were located above the mean value and considered difficult to agree with due to lower endorsability by the students. 2 items (**IFS2 and IFS3**) represent section 1 (understanding the concept of the Islamic financial system) and 4 items (**IFS4, IFS5, IFS6 and IFS7**) represent section 2 (practical knowledge on the Islamic Financial System).
- 2 items (**IFS2 and IFS3**) were located above the mean value. They measured the students' ability to understand the concept of the Islamic financial system, narrate the development of the Islamic financial system, the organization of modern banking operations within the Islamic framework, and how to bridge between surplus and deficit entities and many more. Even though the students had learned about the financial system previously, especially from a conventional perspective, when it comes to the Islamic perspective, it's slightly different. Some of them find it hard to understand how to combine Islamic aspects into the financial system.
- Item **IFS5** on the top part of the map (above item max +56.75logit), indicating that it was considered challenging because the students did not have enough practical knowledge and understanding of the Islamic financial system. Without a good understanding of principles, it becomes the biggest obstacle for students to understand the basic discussion on the Islamic financial system and they become difficult to practice in the future.
- Items **IFS4**, **IFS5**, **IFS6** and **IFS7** related to practical knowledge on the Islamic financial system were also considered difficult. They measured the students' ability to discuss the money market of the Islamic financial system, the importance of the capital market especially in the Islamic financial system, the function of takaful and retakaful within the framework of the Islamic financial system and the types of risks exposed by Islamic financial institutions. The majority of students feel that the practical aspect is challenging for them to understand.

Category of Students

The Wright Map, as shown in Figure 1, reveals that students could be divided into two categories: those who have a good understanding of the Islamic financial system and those who have less understanding based on the $Person_{Mean}$ indicator and their location on the map. Students who are above the $Person_{Mean}$ constitute the group who have a good understanding of the Islamic financial system (**group B**). Conversely, the students below $Person_{Mean}$ constitute the group who are less understanding of the Islamic financial system, and probably some section of EST did not contribute to that (**group A).**

Group "A" has 33 students, or 39 percent (33/84 x 100), who have less understanding of the Islamic financial system and EST probably did not influence them to enhance their understanding and knowledge about the Islamic financial system. One student (P1) indicated low agreement on the items measuring the understanding of the Islamic financial system because it was stated at the bottom of the map (person Min +24.30logit).

Group **B** has 51 students or 61 percent (51/84 x 100) who have a good understanding of the Islamic financial system because they have the ability to understand the concept and practical knowledge of the Islamic financial system. Among 51 students, 1 student was placed at the top of the map (above Person Max +83.72logit), indicating that the student showed good conceptual understanding of the Islamic financial system and the student has the ability to practice the knowledge about the Islamic financial system.

Discussion

The results of this study highlight how useful the Rasch Wright map is for identifying and differentiating students' comprehension of the Islamic financial system. Educators have a powerful tool to improve curriculum design and instructional strategies when they can visualize item difficulty and student competency on a common scale. The instrument demonstrated robust psychometric properties, as evidenced by an item reliability of +0.86 and person reliability of +0.68, indicating its effectiveness in distinguishing varying degrees of conceptual mastery among students.

The Wright Map analysis further revealed that although the majority of students demonstrated satisfactory understanding of the fundamental concepts of the Islamic Financial System, several technical topics—including the Islamic money market, Islamic capital market, takaful, and retakaful—remained relatively challenging. This suggests that students are generally able to comprehend theoretical concepts but experience greater difficulty when applying these concepts in practical or professional contexts. Similar observations have been reported by Bley and Kuehn (2009), who found that students possessed positive perceptions of Islamic finance but demonstrated weaker technical knowledge. Similarly, Saputra and Rahmatia (2021) found that university students demonstrated relatively low levels of Islamic financial literacy, particularly in areas requiring the application of Islamic financial principles. Consistent with these findings, the present study revealed that students encountered greater difficulty with technical topics, such as the Islamic money market, Islamic capital market, takaful, and retakaful, compared with foundational concepts. This suggests that while students possess adequate theoretical knowledge, they require a deeper conceptual understanding and greater ability to apply Islamic finance principles in practical contexts.

Overall, the study demonstrates that the Rasch Wright Map provides valuable evidence for curriculum evaluation and instructional improvement. By identifying both students' competency levels and the relative difficulty of individual concepts, the model enables educators to make evidence-based decisions regarding curriculum design, teaching strategies, and assessment practices. Consequently, the Rasch Measurement Model represents a valuable assessment approach for enhancing the quality of Islamic finance education and promoting continuous improvement in student learning outcomes.

5. Managerial Implications and Recommendations

The study revealed that students generally performed well in foundational and introductory concepts of the Islamic financial system. However, technical areas such as Islamic capital markets, Islamic money markets, takaful, and retakaful posed significant challenges. These findings indicate the need for improved pedagogical approaches that emphasize practical applications, higher-order thinking, and contextual learning in Islamic finance education. Educators may benefit from incorporating case studies, simulations, and problem-based learning strategies to strengthen students' understanding of complex Islamic financial instruments. For example, a case study on takaful could present a realistic scenario involving a participant seeking protection against a specified financial risk, requiring students to identify the appropriate takaful structure, explain the underlying Shariah principles, and distinguish the arrangement from conventional insurance. Such a case-based activity could help students connect the theoretical concepts of takaful with their practical application. Students with weaker conceptual understanding may require additional academic support and targeted interventions. The categorization of students into high- and low-performing groups further highlights the importance of differentiated instruction. Students with weaker conceptual understanding may require additional academic support and targeted interventions.

Conclusion

Overall, this study demonstrates that the Rasch Measurement Model is an effective tool for assessing students' conceptual understanding of the Islamic Financial System course. By simultaneously measuring person ability

and item difficulty, the Rasch Wright Map provides more meaningful diagnostic information than traditional raw-score analysis, enabling educators to identify students' strengths, learning gaps, and challenging course concepts more accurately. The findings support the integration of Rasch-based assessment into Islamic finance education to enhance curriculum evaluation, instructional improvement, and evidence-based decision-making. Nevertheless, this study was limited to first-year Islamic Banking students from a single institution, which may restrict the generalizability of the findings. Future research should involve larger and more diverse samples across multiple higher education institutions and employ longitudinal designs to examine the development of students' conceptual understanding over time. Further studies may also incorporate additional Rasch analyses, such as Differential Item Functioning (DIF) and item fit statistics, to build directly upon the gaps identified in this study—namely, the distinct conceptual difficulties students encountered with complex topics like the Islamic money market, capital markets, takaful, and retakaful (**IFS4–IFS7**. Specifically, item fit statistics should be conducted on revised or expanded test items to detect potential aberrant response patterns or item misfits when assessing these technical areas. Additionally, applying Differential Item Functioning (DIF) would clarify whether the observed difficulty in these specific practical modules stems from genuine conceptual hurdles or potential item bias across different student subgroups (e.g., prior academic background, gender, or previous exposure to conventional finance). Linking these psychometric analyses directly to topic-specific performance will enable researchers and educators to refine individual test items and ensure equitable assessment across diverse learner profiles

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The Effectiveness of Gamified Augmented Reality in Higher Education: A Case Study of MARA 5.0 in a Public University

*Abdul Hamid Abdul Halim[1], Dr Hairulnizam Hashim[2], Masrur Mohd Khir[1], Nor Azzura Nordin[1], Ryan Kang Jee Hong[3], Natalie Loi Yoke Kei[3]
[1]Department of International Business and Management Studies, Universiti Teknologi MARA, Malaysia
[2]Department of Economics and Financial Studies, Universiti Teknologi MARA, Malaysia
[3]Unbound Malaysia Sdn. Bhd., Malaysia
Email: *abdulh2949@uitm.edu.my, hairul1927@uitm.edu.my, masrur@uitm.edu.my, azzura344@uitm.edu.my, ryank@unboundmalaysia.com, nataliel@unboundmalaysia.com
Corresponding Author: Abdul Hamid Abdul Halim

Abstract: This study aims to determine the impact of an augmented reality (AR) game on students' learning experience. The effects of the AR game Mission AR Apocalypse (MARA) 5.0 on students' learning experiences at Universiti Teknologi MARA (UiTM) were assessed. A survey of 750 students was conducted before and after playing the game in June 2024. There were seven dimensions of learning evaluated. Scores significantly increased after the intervention across all areas of learning. The highest increase was in conceptual understanding (mean 2.41 to 4.39), followed by learning motivation (2.23 to 3.93). The results indicate that initial technology-related difficulty was manageable. The findings imply that AR can improve understanding and motivation, but further implementation requires broadening use in challenging subjects, targeted training, and equal access to the devices needed. The results indicate that AR can be used in higher education to support active learning. In many cases, this requires overcoming barriers to usability for students and instructor resistance. The barriers can hinder learning in complex topics.

Keywords: *Augmented reality (AR) games; player satisfaction; immersive experience; post-event behaviour; game design and engagement*

1. Introduction

With all this in mind, we have seen the conversation shift toward looking at ways to innovate in education, particularly through technology (Lampropoulos, 2025). The field of Augmented Reality (AR) has been identified as one of the best places to start, providing a real-world connection between theory and practice. With AR, students no longer need to simply read textbooks or listen to lectures; they can be immersed in an extremely engaging, interactive environment where everything is put to work. As one can imagine, traditionally university students are spoon-fed a diet of textbooks, lectures and maybe some practical labs here and there. While perfectly serviceable for many purposes, they are not always well equipped to help all students digest highly complex concepts or even just the more abstract concepts.

A general lecture may fail to engage visual or kinesthetic learners, which can become problematic in disciplines like science, technology, engineering and math where spatial reasoning and visualization are essential (Pireva & Shatri, 2026). AR steps up to the plate and fills this gap. Trials recently showed that students who learned in an AR-enabled classroom were generally performing better, stayed interested longer and actually understood the content on a much deeper level (Arsyad, Apriansyah, Awaludin, Khasanah & Prasetyo, 2025). Whether students are able to hold it in their hands and turn it around remains an open question. Immediately the cognitive load is lowered. What makes things easier is that improved comprehension of instructional materials is only one of the benefits of using augmented reality (AR), since the addition of fun could also conceivably help memory retention via greater attention and longer periods of engagement. It is not so much about making something new as about structuring the experience of the learner through the use of AR. That is, placing information in a visually meaningful, spatially organized format and prompting them to actively explore may decrease the sense of effort involved in studying and encourage learners to sustain their focus for longer. This is probably dependent on the design decisions made, for instance, if the AR elements are tied to the learning objectives, or if they draw attention away from the focus material.

It is also often touted that AR can accommodate different learning styles at once. For those who require visual stimuli, AR can offer vibrant and spatial representations of concepts that make the relations clearer. This

includes aspects like size, distance, orientation, etc., which are harder to express in static diagrams. For those who are kinesthetic learners, AR can be used to enable learning through represented interactions, for instance, via moving digital objects with hand gestures, moving models around in the environment, or triggering content based on movement. These different modalities could overlap, whereby learners see and act on the same representation, perhaps associating what they see with what they do and what they say. Whether these overlapping modalities are effective will depend on the situation, including the difficulty of the subject matter, the level of the learner, and how easy it is to interact with. As the technology develops rapidly, we can now quantify the impact it has quite easily. Current research certainly seems to imply that game-based AR can indeed drive an educational revolution, improving not only test scores, but important problem-solving skills too (Li, Luo, Chen, Wang, Yin & Zhang, 2025). The systematic review highlights that AR always yields a large, positive effect on instructional quality and real learning outcomes in higher education (Takona, 2024)

Mission AR Apocalypse 5.0 is an augmented reality game created for students at Universiti Teknologi MARA. The game was co-developed by UnBound Malaysia and Event Management students at the university, and it was initially released during the 2021 COVID-19 lockdown. It is now in its fifth iteration. In alignment with the Malaysia Education Blueprint and the Higher Education Digitalisation Agenda, Malaysian public universities are also accelerating their digital transformation to better equip graduates to enter a high-tech economy. As part of the national initiatives of MyDIGITAL (Economic Planning Unit [EPU], 2021a), the National 4IR Policy (EPU, 2021b), and Education 5.0, higher education institutions need to adopt a new teaching and learning model to focus on student-centered active learning via interactive technologies that can decrease the cognitive load while enabling the learning of spatial orientation and critical thinking skills, including solving real-world problems.

Problem Statement

While there is growing adoption of AR in higher education, few studies have evaluated the long-term effectiveness of this new teaching and learning modality. The technology is still relatively new and often viewed as a 'novelty' by educators and students, rather than an essential instructional methodology. AR is therefore seldom applied in a manner that truly taps into its potential as an effective instructional platform. University students also often suffer from a knowledge-action gap, especially in fields like STEM and financial literacy. Students are taught basic theoretical concepts, but conventional educational strategies may not be able to support hands-on implementation and lifelong self-confidence. Traditional university teaching practices still revolve around 'dead' textbooks and one-way lecturing. Existing research indicates that these passive teaching strategies cannot cater to the diverse learning styles of the student population and could lead to boredom and diminished levels of self-motivation to learn, resulting in an elevated mental workload when confronting abstract ideas. This practical knowledge gap is specifically pronounced in fields like financial literacy and business management. Young people tend to know in theory how to save and invest money. Yet they often get confused when faced with actual financial choices. This represents a classic example of the 'knowledge-action gap' (Yong, Yew & Wee, 2018). Financial awareness among young Malaysians is essential for their long-term welfare (Yaacob, Zainuddin & Rohani, 2024). Most of the extant AR education research consists of individual case studies or specific subjects, which sheds no light on how immersive technology can be used to fill these exact behavioral knowledge gaps. We do know from some early studies that AR, specifically if combined with game elements, is highly effective in capturing students' attention (Kodirova, 2025). However, we still do not know enough about its effects on critical thinking, problem-solving, and long-term knowledge retention. We also do not know enough about how different groups of students respond to AR to help us customize it to serve their varied learning needs.

While augmented reality and mobile immersive technologies are being increasingly deployed in university teaching settings, there is a lack of empirical work that helps us to understand how they impact student learning. Much of the existing literature examines small-scale case studies or focuses on specific disciplines. This means we do not yet have a strong understanding of how gamified augmented reality impacts large cohorts of students in public universities, especially with respect to their ability to comprehend concepts, motivation, and confidence in their abilities. This may be part of the reason why people tend to see them more as a novelty than a serious learning tool. Because there is already an overall movement toward greater digitalization in higher education, it makes sense to assess the efficacy of gamified augmented reality systems in a more empirical way, to both allay concerns about their utility, support university investments in new

technology, and offer evidence-based advice about how best to use immersive platforms to teach students across a broad range of disciplines as part of the mainstream curriculum.

Research Objectives

This study evaluates the overall pedagogical effectiveness of a gamified augmented reality (AR) system in enhancing the learning experience of university students. Specifically, the research aims to:

- Assess the impact of gamified AR on student conceptual comprehension and knowledge retention in complex subject areas compared to traditional learning methods.
- Measure changes in student learning motivation, active material engagement, and interactivity following the implementation of the AR system.
- Evaluate post-intervention shifts in student academic self-efficacy, adaptation across the technological learning curve, and overall educational satisfaction.

2. Literature Review

Traditional Learning Techniques vs. Technologies such as AI and AR

The debate over how to best integrate advanced tools like AI and AR into conventional classrooms has dominated recent educational development (Lampropoulos, 2025). For centuries, formal education has leaned heavily on textbooks, lectures, and rote memorization. While reliable, these methods often struggle to accommodate diverse learning styles or foster deep, experiential understanding.

Traditional learning methods: The education system has always been based on textbooks and lectures. They have served us well for hundreds of years, and it is easy to see why. A textbook is a perfect reference tool that one can come back to. And a teacher can broadcast the information to thousands at once through a lecture. It is cost-effective, easy to scale, and supported by an enormous amount of research over hundreds of years. The problem is that textbooks and lectures support passive learning. One just sits there like a sponge soaking up knowledge. This often kills motivation and makes it difficult to retain what one learned. Even worse, most students do not know how to translate theory into practice when they apply it to their jobs or everyday life (Arteaga, Biesbroek, Nalau & Howes, 2024). And a standard lecture cannot simultaneously cater to visual, auditory, and kinesthetic learners, so comprehension gaps naturally occur (Lampropoulos, 2025).

Advanced Technologies: AI and AR are more dynamic and extremely personalized. With AI, instructional differentiation can be taken to another level. Adaptive learning platforms analyze real-time performance and make pacing and content decisions on the fly based on the individual learner's performance gap (Mosha, Chigwada, Ketchiwou & Ngulube, 2026). The personalization cuts down learning deficits tremendously. A systematic review of the role of AI in blended learning in higher education in 2025 revealed that 85.1% of studies reported statistically significant gains in academic achievement, while there was also a 78.7% increase in engagement (Hoogers, Thüring & Michels, 2026). AR is different. It adds virtual content to the physical world. Students can play with 3D objects, go through virtual experiences, and interact with the course in ways not possible before.

Interactivity: Traditional Education Methods vs. AR/AI Technologies

Traditional Education Methods: While dominant, traditional methods offer incredibly low interactivity. The one-way flow of a standard lecture rarely allows for meaningful conceptual exchange, turning what should be an active discussion into a passive case presentation (Beigzadeh, Bazyar, Delzendeh, Razmi & Sharifi, 2024; Boedeker, Schlingmann, Kailin, Nair, Foldes, Rowley, Salciccioli, Maag, Moreno & Ismail, 2025). Textbooks operate the same way; students read and absorb with zero opportunity for active, guided problem-solving.

Augmented Reality (AR) and Business Simulations: This is the passive model that AR shatters. It allows students to bring their ideas to life by combining digital content with real spaces. With AR, students can engage in interactive simulations that allow them to experiment, fail, and learn freely in a completely safe, consequence-free environment. Game-based learning interventions are indicating remarkable results when applied to financial literacy. They boost intrinsic motivation by wrapping complex financial decisions in an engaging story. They also actively discourage behavioral biases such as risky herd behavior or overconfidence (Kosasih & Juhana, 2025). Gamified tools rooted in Human-Computer Interaction (HCI) principles use

immediate feedback loops to successfully guide users through tricky budgeting constraints (Yulianto, Pramono, Wijaya & Nasrun, 2024).

Collaborative Learning with AI and AR: Both technologies excel at fostering teamwork. AI can analyze student profiles to build perfectly balanced groups with complementary skills. Meanwhile, AR provides shared digital spaces where geographically dispersed students can interact and collaborate on 3D models in real-time (Ramli, Mohamad, Kassim, & Puspita, 2025).

Familiarity Problems in Traditional Education Methods Vs. AR/AI Technology

Understanding Traditional Teaching Methods: Despite their flaws, traditional methods have one massive advantage: familiarity. Having been exposed to textbooks and lectures since childhood, both students and educators know exactly what to expect. This predictability dramatically lowers classroom anxiety, allowing students to focus entirely on the subject matter rather than fumbling with a new technological format (Digital Education Council, 2026).

The Technology Acceptance Model (TAM) and Educator Expectations: The Technology Acceptance Model (TAM) suggests that if a person thinks a system is useful and easy to use, then they will adopt it. This perceived ease of use takes a large hit as many teachers have never even heard of AR and AI before, let alone had an opportunity to learn about them. Unlike passing out a syllabus, it takes serious knowledge and effort to implement AR (Davis, 1989). Modern TAM analyses also reveal another aspect: AI anxiety. Faculty and students may be concerned about data privacy, algorithmic bias, and academic integrity issues, which makes them reluctant to wholly embrace this technology. An international survey discovered that although students frequently employ AI, there are several who think it does not genuinely help them better comprehend the material, which proves that transparency and functionality rather than technological novelty are necessary for long-term acceptance (Digital Education Council, 2026).

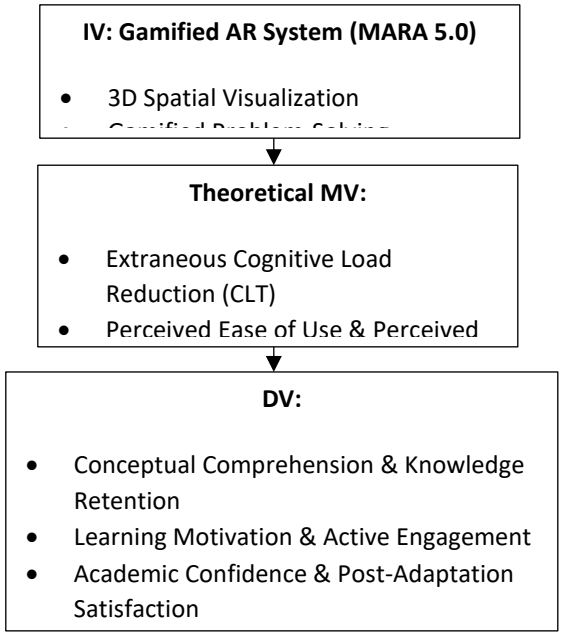
Resistance to Change

Traditional institutions are resistant to AR and AI, mostly because of the high start-up costs of the headsets, weak campus Wi-Fi and the large headache associated with revamping existing curricula. The main problem with adopting AR in the classroom is that research shows that university leadership is concerned about the risks involved. Studies in technology acceptance and use (TAM) and unified theory of acceptance and use of technology (UTAUT) suggest that faculty are often fearful that AI will completely disrupt their teaching style or even worse, it could threaten their future career prospects (Tomovic & Tomovic, 2025). They are also concerned about data privacy and a lack of clear AI governance (Weis, Bele & Erčulj, 2026). For cash-strapped universities, the financial pressure of constantly updating technology leads to university leaders refusing to invest in tools that they do not think they can sustain (Garzón, Patiño & Marulanda, 2025). To combat resistance, universities must not only convince faculty that AR actually works but also ease faculty fears via transparent governance. Faculty who are terrified about AR tools automating their tasks need comfort and thorough training (Al Issa & Maheshwari, 2026). There is no quick fix to rolling out AR; it needs a broad approach, which includes smooth user experience design, broad staff training and specific measures designed to lower instructor fears. And when an institution has a culture that values traditional exams as a means of assessment, there is often a lack of buy-in from administration for a new method like AR.

Theoretical Framework

We combine Cognitive Load Theory (CLT) (Sweller, 1988) and the Technology Acceptance Model (TAM) (Davis, 1989) to show the effectiveness of gamified AR in terms of learning outcomes (Figure 1). These outcomes will ultimately result in post-adaptation satisfaction (Abdul Halim, Mohd Khir, Kang & Loi, 2024). According to CLT, humans have a limited working memory. Students often experience high extraneous cognitive load in traditional lectures because they are required to visualize complicated abstract 3D concepts using 2D media. On the other hand, gamified AR effectively reduces the extraneous cognitive load because it maps digital objects into the real 3D world so that working memory can easily process complex structures. According to TAM, individuals decide to adopt a new technology based on its Perceived Ease of Use (PEOU) and Perceived Usefulness (PU). Gamified AR can increase the PU and PEOU by incorporating interactive game mechanics that foster intrinsic learning motivation, active learning, and academic self-efficacy after adaptation.

Figure 1:Theoretical Framework



Hypothesis

Based on the discussion of the differences between traditional education methods and the use of AR/AI technologies, here are three hypotheses that could be explored in relation to the before and after effects of using AR in education:

H1: By reducing extraneous cognitive load through 3D spatial visualization, students using the gamified AR system will demonstrate significantly higher conceptual comprehension and retention of complex topics compared to traditional learning methods.

H2: Rooted in the Technology Acceptance Model, the interactive and gamified elements of the AR system will significantly increase students' perceived usefulness and intrinsic learning motivation compared to passive lecture-based instruction.

H3: As students overcome the initial technological learning curve, increased perceived ease of use will lead to statistically significant improvements in academic self-efficacy, overall educational satisfaction, and confidence post-intervention.

3. Methodology

The study utilized a repeated-measures design, capturing data through an initial baseline survey and a follow-up survey after the completion of the AR game. The cohort comprised 750 undergraduate and postgraduate students. The demographic breakdown is as follows:

Gender: Women (57%, n = 428); Men (43%, n = 322).

Age Profile: The sample is heavily concentrated around traditional university ages, with 19–20-year-olds constituting over half the cohort (Below 18: 11%; 18: 18%; 19: 27%; 20: 25%; 21: 12%; 22 and above: 7%).

Sampling and Participant Selection

Students participated voluntarily after giving their digital informed consent prior to completing the baseline survey. Data anonymity and data protection protocols were followed for a 45-day secure data retention period. The students were recruited through a purposive sampling method where they participated in the Mission AR Apocalypse (MARA) 5.0 event held at Universiti Teknologi MARA (UiTM). Inclusion criteria consisted of currently enrolled university students who were actively using the MARA 5.0 AR modules during the event time frame in June 2024. A total of n = 750 students participated in this study.

Instrumentation and Reliability

A 12-item questionnaire with 5-points on a Likert scale from 1 (Strongly Disagree) to 5 (Strongly Agree) was used as a research tool. The content validity of this questionnaire was checked through the opinions of experts who were educated in the field of educational technology. To determine the reliability of the construct, Cronbach's alpha (α) was used. In addition to obtaining high reliability (α = 0.82), Cronbach's alpha (α) in the pretest (0.82) and after the intervention (0.86) was higher than the acceptable value in academic studies (0.70).

Statistical Analysis

Data were analyzed using SPSS statistical software. To account for the within-subject, repeated-measures research design, a Paired-Samples t-Test was conducted to evaluate mean score differences across all pedagogical dimensions pre- and post-AR intervention. Statistical significance was set at an alpha level of 0.05. Practical significance was evaluated using Cohen's d to determine effect sizes.

4. Results

Here is the formatted statistical difference test result table based on the analysis of the 750 surveyed students:

Table 1: Paired-Samples t-Test (N = 750, df = 749)

Core Pedagogical Dimension	Pre-AR Mean (SD)	Post-AR Mean (SD)	Mean Shift (ΔM)	t-Statistic (df=749)	p-Value	Cohen's d (Effect Size)
Material Engagement	2.76 (1.01)	3.79 (0.98)	+1.02	19.88	< 0.001	1.03 (Large)
Interactivity	3.05 (1.26)	3.85 (0.91)	+0.80	14.09	< 0.001	0.73 (Medium-Large)
Conceptual Comprehension	2.41 (0.81)	4.39 (0.83)	+1.98	46.76	< 0.001	2.41 (Extremely Large)
Learning Motivation	2.23 (0.92)	3.93 (0.97)	+1.71	34.92	< 0.001	1.80 (Extremely Large)
Teaching Effectiveness	3.21 (1.12)	3.47 (1.13)	+0.27	4.55	< 0.001	0.24 (Small)
Academic Confidence	3.06 (0.95)	3.33 (1.09)	+0.26	5.02	< 0.001	0.26 (Small)
Overall Satisfaction	3.34 (0.98)	3.59 (1.14)	+0.25	4.48	< 0.001	0.23 (Small)

Table Interpretation Key

The core statistical metrics in the results tables evaluate the significance, magnitude, and practical impact of the AR intervention (Table 1):

t-Statistic: Measures the size of the score difference relative to the variation within the student sample. An absolute value of $t > 1.96$ indicates statistical significance at the 95% confidence level ($\alpha = 0.05$).

p-Value: Represents the probability that an observed shift occurred purely by random chance. A value below 0.05 (or < 0.001) confirms the results are statistically significant, allowing for the rejection of the null hypothesis.

Mean Shift (ΔM): Shows the exact numeric change between baseline (pre-AR) and follow-up (post-AR) average scores on the 1–5 Likert scale.

Cohen's d (Effect Size): Measures the practical strength or real-world impact of the AR tool, independent of sample size (0.2 = small, 0.5 = medium, 0.8+ = large/substantial).

Core Statistical Insights

Absolute Rejection of the Null Hypothesis (H0): For each of the 7 core pedagogical aspects tested, the p-values are extremely low, which suggests that it is unlikely that the improvements we see are due to chance variation.

Substantial Effect Sizes in Comprehension & Motivation: The t-statistics for Conceptual Comprehension ($t = 46.760$) and Learning Motivation ($t = 34.920$) are high. This is an indication that there has been a fundamental change in the students.

Validation of Marginal Shifts: Even though the mean shifts, such as Institutional Teaching Effectiveness (+0.27) and Academic Confidence (+0.26), look trivial, the t values (4.555 and 5.020) indicate that these changes are statistically significant and are worth noting, particularly when the sample size is so large (N = 750).

Discussion

The statistical results strongly support all three of the researchers' hypotheses, proving that the MARA 5.0 AR game successfully transformed the students' educational experience. All tested dimensions yielded a p-value of <0.001, allowing for an absolute rejection of the null hypothesis across the board.

Hypothesis 1: Understanding and Retention

This metric saw the most profound transformation in the entire study. The baseline mean for comprehension was incredibly low at 2.41, but post-AR implementation, it skyrocketed to 4.39. The mean shift of +1.98 combined with an exceptionally high t-statistic (46.760) confirms that H1 is absolutely validated. AR clearly succeeded in making complex concepts more understandable than traditional methods.

Hypothesis 2: Engagement and Motivation

Learning Motivation experienced a massive effect size, jumping from a frustrated baseline of 2.23 to 3.93 (+1.71 shift, t=34.920). Similarly, Material Engagement rose from 2.76 to 3.79 (+1.02 shift, t=19.882), and Interactivity improved by +0.80. The massive t-statistics and positive mean shifts verify H2. Moving away from a frustrating baseline environment, the gamified AR system successfully pulled the student population distribution into an overwhelmingly positive and motivated learning zone.

Hypothesis 3: Adaptation and Satisfaction

While the mean shifts for these metrics are smaller (Overall Satisfaction +0.25, Academic Confidence +0.26, Teaching Effectiveness +0.27), they are fully verified as real improvements driven by the large sample size of 750 students. These marginal but highly significant positive shifts support H3. Despite any initial unfamiliarity or learning curve, the post-AR scores prove that students adapted well, resulting in statistically verifiable increases in their overall academic confidence and satisfaction with the teaching method ($p<0.001$).

Summary of Empirical Findings

Our results show that MARA 5.0 does influence how students learn complex concepts. There was a large shift in conceptual understanding ($\Delta M = +1.98$, $d = 2.41$) due to the impact of 3D spatial visualization on cognitive processing. According to Cognitive Load Theory (Sweller, 1988), it makes sense to replace a static 2D diagram with an interactive spatial model, as it will reduce extraneous cognitive load, which allows for more efficient working memory capacity to be applied towards core concepts. Our results are consistent with other studies (Pireva et al., 2026; Li et al., 2025) that imply that spatial immersion leads to faster acquisition of concepts within complex topics.

From the perspective of motivation, confidence, and the tech curve, the presence of gamification elements increased learning motivation ($\Delta M = +1.71$, $d = 1.80$) because they helped to meet the needs for autonomy and competence, as posited by Davis (1989). It is possible that some students may have entered into a flow state, where their actions become intrinsically motivated, as described previously. The impact on academic confidence ($\Delta M = +0.26$, $d = 0.26$) was not as significant as on motivation.

Because students need to feel in control of the new technology in order to develop real self-efficacy, they need to gain experience using it repeatedly so that their confidence builds up. This could be why the procedural concept of personal budgeting developed more slowly ($\Delta M = +0.39$, $d = 0.42$) compared with the declarative concept of types of investments ($\Delta M = +1.89$, $d = 3.04$). Gamified AR is valuable and delivers more than just satisfaction. This reveals how gamified AR provides a personalized, multi-sensory learning environment that addresses many of the criticisms of traditional instruction. The results support the arguments made previously by Abdul Halim et al., (2024).

We showed how MARA 5.0 can offer a customizable, multisensory experience. This study solidifies the view that AR is a formidable pedagogical tool capable of driving genuine engagement, motivation, and deep conceptual understanding, thereby securing long-term educational outcomes.

5. Conclusion and Recommendations

Recommendations

Based on the observed success of the MARA 5.0 system and identified theoretical challenges, the following recommendations are proposed for university leaders and ed-tech developers.

Scaling AR Integration Across Complex Disciplines

The significant increase in comprehension warrants moving AR beyond isolated trials into standard curricula, particularly in disciplines facing the "knowledge-action gap" such as STEM, advanced business management, and financial literacy. Institutionalizing platforms like MARA 5.0 can shift student bodies from passive reception to active problem-solving.

Comprehensive Professional Development for Educators

Addressing faculty unfamiliarity and "AI anxiety" is crucial for AR adoption. Universities should invest in faculty professional development programs that focus on pedagogical alignment, demonstrating how to integrate gamified modules into existing syllabi. Transparent support addressing fears related to technological displacement will reduce resistance and promote effective AR utilization.

Addressing the Student Learning Curve and Accessibility

The modest gains in Academic Confidence suggest a residual technological learning curve. Future AR implementations should include low-stakes, intuitive onboarding tutorials to build student confidence early on. Furthermore, administrators must ensure equitable access to necessary hardware and network infrastructure to prevent widening the digital divide.

Designing for Long-Term Behavioral Change

Ed-tech developers should continue to apply Human-Computer Interaction (HCI) principles to enhance the social interactivity and realism of simulations. For subjects like financial literacy, incorporating elements such as real-time economic stressors and peer-to-peer collaboration could help sustain the observed increases in intrinsic motivation.

Future Research Directions

While this study confirms AR's immediate impact on engagement and comprehension, future research should track longitudinal outcomes to assess knowledge retention over extended periods. Additionally, investigating how different demographic groups interact with AR could provide data for developing more personalized learning environments.

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Islamic Debt Principles: A Conceptual Framework for Ethical and Asset-Backed Financing

*Zahariah Sahudin, Marhani Mohamed Anuar, Hartini Zuhaila Jamal, Heizal Hezry Omar
Faculty of Business and Management, Universiti Teknologi MARA, Bandar Puncak Alam, Selangor, Malaysia
Email: *zahariah128@uitm.edu.my, marha558@uitm.edu.my, hzj@uitm.edu.my, heizalhezry@gmail.com
Corresponding Author: Dr Zahariah Sahudin

Abstract: This paper constructs a novel three-pillar conceptual framework for Islamic finance, built upon a rigorous methodological foundation that synthesizes two distinct intellectual disciplines. From Islamic jurisprudence, specifically *Usul al-Fiqh* and *Maqasid al-Shariah*, the framework derives its ethical and legal boundaries for permissible contracts. From financial economics, drawing on risk agency theory, it obtains its economic principles for asset ownership and equitable risk distribution. The framework's development is critically informed by a gap analysis of existing literature, particularly the works of El-Gamal and Chapra, which exposes a persistent and troubling disconnect between Islamic finance's proclaimed ethical ideals of risk-sharing and its actual practice of risk-transfer through debt-mimicking instruments. Using deductive reasoning from first principles of Islamic ethics, the paper derives the framework's core components and then stress-tests them against modern banking products. The proposed framework advances three interdependent pillars: first, strict adherence to ethical rules grounded in Islamic law; second, tangible real asset ownership that links financial transactions to the productive, real economy and third, genuine risk-sharing between financiers and borrowers. The paper argues that these pillars must function interdependently, because legal compliance alone is insufficient. This insufficiency is powerfully illustrated by *tawarruq* (commodity *Murabaha*) products, which check procedural boxes yet lack both real asset ownership and true risk-sharing, rendering them economically indistinguishable from interest-based debt. To transcend the conventional *halal-haram* dichotomy, the framework proposes a "spectrum of *Islamicness*"—a sophisticated evaluative matrix that reveals how most current Islamic banking products score well on legal formality but poorly on economic substance.

Keywords: *Ethical finance, Islamic jurisprudence, Maqasid al-Shariah, tawarruq and commodity Murabaha.*

1. Introduction

Background of Study

The global financial system faces persistent structural challenges. Recurring economic crises from the 2008 subprime meltdown to the sovereign debt turbulence in Europe, have exposed fundamental weaknesses in conventional banking. Excessive risk-taking, speculative bubbles, systemic contagion, and widening inequality (Stiglitz, 2010; Reinhart & Rogoff, 2009). These failures have resulted in a global rethinking of financial ethics, and new movements such as sustainable finance, ESG (Environmental, Social and Governance) investing and impact investing have emerged, aiming to direct capital allocation to wider social benefits (Schoenmaker, 2017; Eccles et al., 2014). Islamic finance has emerged as a leading alternative in this broader reformation, promising an ethical, asset-backed and risk-sharing model of intermediation.

Conventional finance has some key elements that are prohibited in Islamic finance which is based on *Shariah* (Islamic law). First, it forbids *ribā* (interest or usury), which is defined as any predetermined, positive return on money lent, irrespective of the outcome of the enterprise. Second, it prohibits *gharar* (excessive uncertainty or ambiguity) in contractual terms, including speculative sales of what one does not own. Third, it prohibits maysir (gambling or pure speculation) and requires that all financial transactions be supported by real, tangible assets and authentic economic activity (El-Gamal, 2006; Chapra, 2008). The two fundamental contracts in Islamic finance are *muḍārabah* (profit-sharing partnership) and *mushārakah* (joint-venture partnership). In *muḍārabah*, one party provides capital and the other provides entrepreneurial effort, with profits shared according to an agreed ratio, while losses are borne solely by the capital provider. In *mushārakah*, all partners contribute capital and share profits and losses proportionally to their investment (Iqbal & Mirakhor, 2011). These contracts represent the normative ideal of risk sharing, aligning incentives of the financier and the entrepreneur, and encouraging productive economic activity.

Problem Statement

But despite these ethical aspirations, a disturbing chasm has opened up between the normative ideals of Islamic finance and its operational reality. The industry has grown rapidly–global Islamic financial assets are estimated to exceed USD 4 trillion and are projected to reach nearly USD 5 trillion by 2026 (IFSB, 2023). But this growth has been overwhelmingly driven by debt-mimicking products, not genuine risk-sharing instruments. Contracts such as *murābaḥah* (cost-plus sale) and *tawarruq* (commodity Murabaha) that are structurally similar to conventional loans with fixed, predetermined returns, now constitute over 70% of Islamic banking assets in many jurisdictions, while *muḍārabah* and *mushārakah* make up less than 10% (Ernst & Young, 2016; Ahmed, 2021).

Likewise, the global *ṣukūk* (Islamic bond) market has grown to almost USD 1 trillion, but many *ṣukūk* structures are "asset-based" as opposed to genuinely "asset-backed". In an asset-backed *ṣukūk* investors have rights to cash flows from an asset, but do not own the underlying asset. This way, they do not bear the full risks of ownership such as destruction, depreciation, or impairment, and the structure transfers the risk to the obligor that performs the same economic function as a conventional bond (El-Gamal, 2006; MIFC, 2021).

This gap between form and substance threatens the very raison d'être of the industry. The danger is that if Islamic banks continue to market products that are Shariah-compliant only in the sense of legal documentation and economically indistinguishable from conventional debt, the industry risks becoming nothing more than an "interest arbitrage" mechanism, what El-Gamal (2006) famously called "Islamic finance in name only. This credibility gap not only erodes consumer trust but exposes the industry to charges of hypocrisy and ethical irrelevance.

Connecting Islamic Debt Principles with Broader Global Trends

The issues discussed in this paper are not unique to Islamic finance but are rather a manifestation of global trends toward sustainable and ethical finance. The shift in capital markets toward ESG integration, driven by the United Nations' Sustainable Development Goals (SDGs) and the Paris Agreement on climate change (UNEP FI, 2022; World Bank, 2021), has seen investors increasingly demanding that financial intermediaries demonstrate positive social and environmental impact, in addition to financial returns.

The basic principles of Islamic finance are remarkably in tune with these global trends. The prohibition of *riba* discourages speculation based on debt and excessive leverage. Mirakhor & Iqbal (2013) describe the main contributors to systemic risk and financial instability. The prohibition of *gharar* (excessive uncertainty) promotes transparency and contractual clarity, both of which are key pillars of ESG disclosure standards. The ban on *maysir* (gambling) shifts capital from speculative activities (e.g., derivatives trading) to productive, real-economy investment, a goal common to impact investing frameworks (Scharf & Scholtens, 2022). In addition, the *maqāṣid al-Sharīʿah* (higher objectives of Islamic law) which include the protection of wealth, life, intellect, lineage and faith, are compatible with the "social" and "governance" pillars of ESG that focus on human welfare, responsibility for the environment, and distributive justice (El-Halaby & Hussainey, 2015; Jan et al., 2021).

However, this alignment remains largely theoretical. The current *debt-mimicry* model of Islamic banking does not deliver on these ethical promises. Fixed-return, asset-based products do not incentivize financiers to monitor entrepreneurial performance, do not cushion losses during downturns, and do not contribute to financial stability in the way that genuine risk-sharing would (Askari et al., 2012). In fact, the conventionalization of Islamic finance arguably exacerbates the very problems, inequality, instability, and financialization - that sustainable finance movements seek to address. This disconnection represents not only a religious or legal problem but also a missed opportunity for Islamic finance to position itself as a leading contributor to global sustainable development and responsible investing.

This paper is conceptual in nature and does not present primary empirical data. It is about the structure of Islamic finance contracts, not pricing or operational implementation. The paper is organized as follows: Section 2 gives a review of the literature on Islamic debt, risk-sharing and the form versus substance debate. Section 3 presents the three-part conceptual framework. In Section 4, the framework is used to evaluate existing products and discuss implications. Section 5 concludes with directions for future research.

2. Literature Review

Islamic Debt Financing: Conceptual Foundations

Islamic debt financing occupies a unique position within the broader Islamic financial system. Islamic debt instruments are based on sales, leases or partnerships and must follow Shariah prohibitions on *ribā* (interest), *gharar* (excessive uncertainty) and *maysir* (gambling) (El-Gamal, 2006; Usmani, 2002). Unlike conventional debt which is essentially a loan of money for a fixed interest payment. This structural difference is not just a semantic one; it is a deeper philosophical commitment to linking financial returns to productive economic activity and real risk-taking.

The most common Islamic debt contracts are *murābaḥah* (cost-plus sale) in which a financier purchases an asset and sells it to the client at an agreed markup; *ijārah* (leasing) in which the financier leases an asset to the client at a fixed rental payment; and *tawarruq* (commodity murabaha), a structured transaction involving the purchase and sale of commodities to generate liquidity (Iqbal & Mirakhor, 2011). These contracts are Shariah-compliant technically as far as their legal form is concerned. However, they produce economic results that are very similar to conventional interest-based loans. These results are in the form of fixed, predetermined returns and are largely independent of the performance of the underlying asset (Khan, 2025).

The main business model in Islamic banking is reliance on debt-like products. Empirical data shows that more than 70% of Islamic banking assets in countries such as Malaysia, the Gulf Cooperation Council (GCC) countries and Indonesia are *murābaḥah, ijarah* and *tawarruq* (Ernst & Young, 2016; Ahmed, 2021; Muneem et al., 2024). In contrast, real profit-and-loss sharing (PLS) contracts *muḍārabah* and *mushārakah* account for less than 10%. This imbalance begs critical questions about whether the industry is living up to its ethical promise or simply repeating conventional finance in Islamic garb.

Theoretical Basis: Theories of Islamic Debt

The theoretical underpinnings of Islamic debt financing are built on three interconnected principles drawn from the *Qur'an, Sunnah*, and centuries of Islamic jurisprudence (*fiqh*). These principles form the normative framework within which all financial contracts must be assessed.

The Prohibition of *Ribā* (Interest): The fundamental prohibition in Islamic finance is of *ribā*, which is usually taken to mean any predetermined and guaranteed return on money lent, regardless of the outcome of the enterprise (Chapra, 2008). The *Qur'an* explicitly condemns *ribā* in several verses (e.g., *Qur'an 2:275-279*), equating it with injustice and exploitation. Crucially, the ban is not on the rate of interest, but on the structure of the transaction: money should not generate money without being intermediated through real economic activity, risk-taking, and value creation (El-Gamal, 2006). This is the principle that sets Islamic finance apart from conventional debt, where interest is just the price of money over time.

Asset-Backing Requirement (*Al-'Aqd 'Alā Al-'Ayn*): The second cornerstone is that all financial transactions must be tied to an underlying tangible asset, service or real economic activity. This is known as asset-backing. In Shariah, a sale of what one does not own, a sale of non-existent goods or a purely monetary sale with no underlying asset is invalid (Usmani, 2002). The requirement is designed to prevent excessive uncertainty (*gharar*) and gambling (*maysir*) and to ensure that finance serves the real economy and does not become a speculative end. This entails, in practice, that Islamic debt contracts must involve the transfer of ownership (or beneficial rights) of a real asset and the financier must bear the risks associated with that ownership, at least for a meaningful period (Iqbal & Mirakhor, 2011).

The Principle of Risk-Sharing (*Al-Ghunm Bil-Ghurm*): The third theoretical pillar is the maxim *al-ghunm bil-ghurm*, which means "profit comes with risk". Based on a well-known *Prophetic* tradition, this principle states the rule that any entitlement to gain is subject to the corresponding risk of loss (Chapra, 2008). In the case of debt financing this means that the return of a financier cannot be fixed or guaranteed but must vary with the actual performance of the asset or enterprise being financed. This is precisely the reason why the PLS contracts (*muḍārabah* and *mushārakah*) are the normative ideal in Islamic finance, they represent a risk-sharing arrangement by balancing the interests of the financier and the entrepreneur. Because financiers bear the downside risk, they have more incentives to monitor and facilitate the ventures they finance, which may lead

to less moral hazard and better economic results (Mirakhor & Iqbal, 2013; Khan, 2019).

Ethical and Asset-Backed Principles of Islamic Debt

Apart from these theoretical principles, Islamic debt financing is also based on a wider ethical foundation that stresses justice (*ʿadl*), fairness (*insāf*) and social welfare (*maṣlaḥah*). Chapra (2008) argues that the objective of Islamic finance is not only to avoid the prohibition of certain acts but also to promote human welfare, reduce inequality and promote economic stability. This ethical dimension is operationalized by the *maqāṣid al-Sharīʿah* (higher objectives of Islamic law) which include the protection of faith, life, intellect, lineage and wealth. Any financial contract that undermines these objectives, e.g. by aggravating debt distress, promoting speculation or widening inequality, fails the ethical test even if it is technically compliant with *Shariah* (El-Halaby & Hussainey, 2015).

This ethical vision is connected to the asset-backed requirement. If the financier owns the asset then they have the risks of the asset (depreciation, destruction or impairment) and are incentivized to ensure it is used productively. This is quite different from pure monetary lending, where the lender has no interest in the success of the borrower's endeavor, and can call in his money regardless of the results. Thus, the asset-backed approach encourages productive finance instead of speculative finance. The approach is in line with broader global movements toward sustainable and responsible investing (Scharf & Scholtens, 2022; Jan et al., 2021).

Yet, as the literature increasingly demonstrates, the practical implementation of these ethical and asset-backed foundations has been patchy, at best. Many Islamic banks do not see asset ownership as a real issue, but a legal formality, such as holding title for a fraction of a second in *tawarruq* transactions or structuring *sukuk* as "asset-based" rather than "asset-backed" (El-Gamal, 2006; Safutra, 2026). The division of legal form from economic substance is a fundamental betrayal of the ethical and asset-backed ideals that Islamic finance claims to stand for.

Sukuk: The Ideal and the Reality

Sukuk (often termed Islamic bonds) are one of the most important innovations in modern Islamic finance. Unlike traditional bonds, which are a debt obligation of the issuer, *ṣukūk* are structured to reflect shared ownership of an underlying asset, project or business venture. *Ṣukūk* holders have a right to a share of the returns generated by the asset and are exposed to the risks of ownership (Usmani, 2002; AAOIFI, 2025).

The global *ṣukūk* market has grown substantially, with outstanding *ṣukūk* expected to exceed USD 1 trillion by 2025, driven by sovereign issuers in Malaysia, Saudi Arabia, Indonesia, and the GCC, as well as increasing interest from non-Muslim jurisdictions such as the United Kingdom and Luxembourg (Noorali, 2025; Fitch Ratings, 2024). This growth has been celebrated as evidence of the global appeal of Islamic finance and its ability to raise long-term capital for infrastructure and development projects.

However, a growing body of critical scholarship has revealed a significant disconnect between the *ṣukūk* ideal and its market reality. The main critique, most eloquently expressed by El-Gamal (2006), is that most of the *ṣukūk* are "asset-based" and not really "asset-backed." In an asset-backed *ṣukūk*, the issuer does not transfer full legal ownership of the underlying assets to the *ṣukūk* holders. The issuer does not transfer ownership but gives the holders beneficial rights to cash flows from the assets. The structure then creates a contractual obligation on the issuer to pay returns, which in many cases are fixed and predetermined, and which, essentially, reproduces the economic function of a traditional bond (MIFC, 2021).

Indeed, this critique is empirically well founded. Debt-based *sukuk* structures (mostly *ijarah* and *murabaha*) still represent about 70-80% of the global *sukuk* market, while equity-based structures (*mudharabah* and *musharakah*) remain a small minority (Safutra, 2026; Ibrahim & Alenezi, 2024). The prevalence of debt-like *ṣukūk* means that investors do not really share in the risks of the underlying assets – they get fixed returns regardless of the performance of the assets, while the obligor bears the economic burden. As provocatively stated by El-Gamal (2006, p. 124), this is "Islamic finance in name only".

The Divide between Theory and Practice

The theory-practice gap in Islamic finance is a well-documented phenomenon in the extant literature. The

theory-practice gap is a gap between the normative ideals expressed in Shariah texts and the operational realities of the industry. Islamic banking is Shariah-compliant in form and conventional in function. (Khan, 2025) "Banks use the legal forms of Shariah-approved contracts (sales, leases, partnerships), but they engineer them to produce the same economic effects as conventional interest-based loans: fixed, predetermined returns, limited risk exposure, and little monitoring of entrepreneurial performance.

Several factors explain this gap. First, risk aversion on the part of banks, PLS contracts (*muḍārabah* and *mushārakah*) expose financiers to genuine downside risk, including the possibility of total loss of capital. Banks like the predictability of fixed income products because of capital adequacy rules and the shareholders' desire for consistent earnings (Muneem et al., 2024). Second, information asymmetry, PLS contracts require banks to closely monitor and evaluate entrepreneurial projects, which is costly and difficult, especially for small and medium enterprises (SMEs) (Khan, 2019). Third, the Basel capital standards-based regulations consider PLS assets as riskier and require higher capital charges, which further discourages their use (Askari et al., 2012).

Empirical evidence from Malaysia – one of the most developed Islamic finance jurisdictions – suggests that banks view customers as debtors with fixed instalments rather than business partners (Muneem et al., 2024). Such a creditor-debtor relation is fundamentally in contradiction to the spirit of partnership that Islamic finance claims to promote. Similarly, Ibrahim and Alenezi (2024) state that Islamic finance has significant potential for sustainable development (particularly in financing green infrastructure and social enterprises), but this potential is often unrealized because institutions are unwilling to participate in the real risk sharing needed by early-stage ventures.

Regulatory Initiatives to Bridge the Gap

Regulatory and standard-setting bodies have responded to the growing gap between form and substance by taking steps to reform Islamic financial practice. In 2025, the Accounting and Auditing Organization for Islamic Financial Institutions (AAOIFI), the entity that issues globally accepted standards for the Islamic finance industry, issued its Standard No. 62 on *Ṣukūk* (AAOIFI, 2025). This standard is a major regulatory intervention designed to bring *ṣukūk* structures closer to true asset ownership and risk-sharing.

The main provisions of AAOIFI Standard 62 are:

- Prohibition of fixed or guaranteed returns in equity-based sukuk structures.
- Clear legal title transfer to ṣukūk holders, who must bear the risks of ownership.
- Tougher disclosure rules on asset valuations, cash flow projections, and risk factors.

Many scholars and practitioners welcome these reforms as a necessary correction toward the ethical roots of Islamic finance, whereas others worry about possible market disruptions. The implementation of Standard 62 requires a basic overhaul of existing structures of *ṣukūk*, which could lead to higher transaction costs, lower issuance volumes and discourage conventional investors used to bond-like returns (Safutra, 2026). But proponents counter that these transitional costs are unavoidable if the industry is to retain its credibility and long-term viability.

Summary of Literature Review

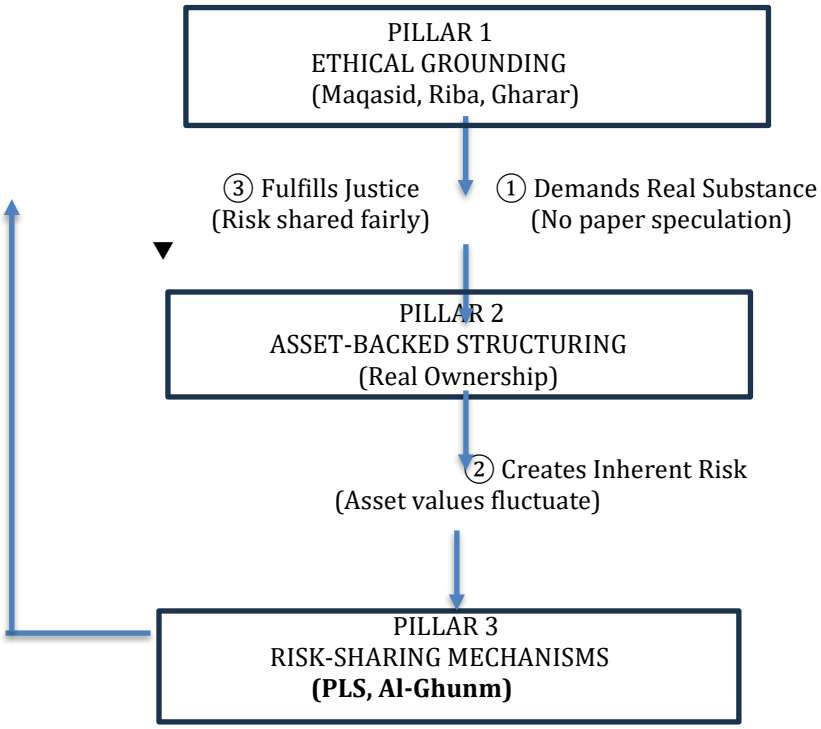
This literature review has identified three basic principles on which Islamic debt financing is theoretically founded, namely the prohibition of ribā, the asset-backing requirement, and the principle of risk-sharing (*al-ghunm bil-ghurm*). However, the practical implementation of these principles has been inconsistent, with the industry dominated by debt-mimicking products (*murābaḥah*, *ijārah*, *tawarruq*, and asset-based *ṣukūk*) that satisfy formal Shariah requirements but replicate the economic functions of conventional debt. Regulatory efforts such as AAOIFI Standard 62 represent a welcome correction, but the literature remains fragmented, descriptive, and yet to fully integrate recent regulatory changes. These gaps motivate the construction of the integrated, tripartite framework presented in the following section.

3. Theoretical Framework

Overview of the Three-Pillar Model

We propose a framework based on three interdependent pillars. We call these Ethical Grounding, Asset-Backed Structuring, and Risk-Sharing Mechanisms. They are connected in a cycle. Each pillar supports and requires the others.

Figure 1: The Three-Pillar Framework for Islamic Debt Principles



Pillar 1: Ethical Foundations

This pillar is the basic rules that have been derived from Shariah. Not only to refrain from the forbidden (*haram*) but to attain the higher purposes of Islamic law (*maqāṣid al-Sharīʿah*) comprising the protection of faith, life, intellect, lineage and wealth. In practice, this pillar involves:

No Riba: The lender cannot charge a fixed guaranteed return. Profit must be uncertain and tied to effort.

No Gharar: Contracts must be clear and without excessive uncertainty. Both parties must know exactly what they are getting.

No Maysir: Transactions cannot be speculative or gambling-like. They must serve genuine economic needs.

Pillar 2: Asset-Backed Structuring

This pillar requires that every transaction is tied to a real, identifiable asset or economic activity. This is what prevents Islamic finance from becoming pure financial engineering. There is a critical distinction here:

Asset-based: The contract mentions an asset, but the financier does not take legal ownership or bear the risks of that asset.

Asset-backed: The financier actually owns the asset and takes the risks that come with ownership (e.g., damage, depreciation).

Our framework insists on the asset-backed version. True ownership is critical. This is in line with AAOIFI Standard 62, which requires that sukuk holders have full legal title to the underlying assets and that returns are linked to the actual performance of the underlying assets

Pillar 3: Risk-Sharing Mechanisms

This pillar implements the rule "gain accompanies risk." If a financier provides capital, he must accept that he might lose it. He cannot just pass all losses to the entrepreneur and keep a fixed return for himself. The best

way to do this is through *Profit-Loss Sharing* (PLS) contracts such as *Mudarabah* (one provides the capital and the other the labor) and *Musharakah* (both contribute capital and management). Under these contracts, profits are shared according to an agreed ratio and losses are borne strictly in proportion to the capital contribution. Even in contracts based on sales, there may be risk sharing. For instance, in *an ijarah* lease, the lessor bears the risk of damage to the asset during the lease period.

How the Pillars Interact (The Relationship View)

The pillars are not independent. They form a logical sequence and a feedback loop:

Ethical Grounding → Demands → Asset-Backed Structuring: Since ethics prohibit money being created from nothing, financing has to be tied to real assets.

Asset-Backed Structuring → Creates → Risk-Sharing Mechanisms: The financier can't escape the risk of real assets falling in value. This means there must be a sharing arrangement.

Risk-Sharing Mechanisms → Fulfills → Ethical Grounding: Sharing risk fairly is the practical definition of justice (*'adl*), which is the heart of the *maqāṣid.*

The System Collapses if One Pillar Fails:

If a sukuk is asset-based (lacks Pillar 2), it does not create real risk for the investor. The investor receives a fixed return violating Pillar 1 (Riba) and Pillar 3 (No risk sharing). If a product shares risk but does not have real assets (Pillar 2) it is gambling (breaking Pillar 1).

Propositions for Testing

Based on the tripartite framework developed in this paper, we propose the following propositions for future empirical research. Each proposition is derived from the logical relationships among the three pillars and is designed to be testable using quantitative or qualitative methods.

The Core Functional Relationship: At the heart of our framework is the assertion that the three pillars are mutually reinforcing and non-fungible. The "Islamicity" (or substantive Islamic authenticity) of any financial contract is a function of the concurrent existence and strength of all three pillars. It can be written as this relation:

This relationship can be expressed as:

$$\text{Islamicity} = f(E, A, R)$$

Where:

E = Ethical Foundations (Pillar 1) — the extent to which the contract upholds *maqāṣid al-Sharīʿah*, justice, and social welfare beyond mere legal formalism.

A = Asset-Backed Structuring (Pillar 2) — the degree of genuine, constructive ownership of real assets, including full liability for risks such as depreciation, destruction, and impairment.

R = Risk-Sharing (Pillar 3) — the degree to which the financier's return is directly and proportionally linked to the realized performance of the underlying asset, and the financier bears downside risk.

This function is multiplicative rather than additive:

$$\text{Islamicity} \propto E \times A \times R$$

This multiplicative relationship captures the core argument of this paper: if any pillar is absent or weak (approaching zero), the overall Islamicity collapses toward zero, regardless of how strong the other pillars are. In other words, legal compliance (high E) without genuine asset ownership (low A) and risk-sharing (low R) does not produce a substantively Islamic contract. Conversely, risk-sharing (high R) without ethical grounding (low E) is directionless and may lead to unjust outcomes. The three pillars must coexist and reinforce one another.

This relationship also allows for a spectrum of Islamicity—products can be graded along a continuum rather than a binary *halal*/*haram* classification, depending on the relative strength of each pillar.

Testable Propositions

Based on this functional relationship and the analytical framework presented in Sections 3.3–3.5, we propose the following propositions for future empirical investigation:

P1: Legitimacy and Trust Proposition

P1: Islamic banks and sukuk that clearly satisfy all three pillars (ethical, asset-backed, risk-sharing) will have higher levels of customer trust and stakeholder legitimacy.

This proposition is based on stakeholder theory and legitimacy theory (Suchman, 1995; Freeman, 1984). When financial institutions genuinely apply ethical principles (Pillar 1), back their contracts with real assets (Pillar 2) and share risks with their clients (Pillar 3), they are perceived as more trustworthy and authentic. This perception helps to increase brand loyalty, customer retention and overall market positioning. Conversely, institutions that "check the box" on Shariah compliance without actually engaging in conventional business are subject to reputational and consumer skepticism, as documented by El-Gamal (2006) and Khan (2025).

P2: Financial Resilience Proposition

P2: Asset-based sukuk (strong Pillar 2) will exhibit higher resilience in terms of stable returns and lower default rates compared to asset-based sukuk during periods of recessions.

The literature on risk sharing (Askari et al., 2012; Mirakhor & Iqbal, 2013) suggests this proposition. In real asset-backed structures investors take on the risks of the underlying asset, so that in downturns returns decline but the structure does not generate domino effects as losses are borne by investors and not by a single obligor. The risk is transferred to the obligor in asset-based or debt-like structures, however, which results in higher default rates if cash flows fall. This is consistent with the empirical evidence that equity-like risk-sharing instruments are more resilient during a systemic crisis (Akin et al., 2016; Khan, 2019).

P3: Regulatory Impact Proposition

P3: Regulatory changes like AAOIFI Standard 62 which enforces Pillars 2 and 3 will increase structuring costs initially but will result in greater long-term market stability and ethical credibility.

This proposition is grounded in institutional theory and regulatory economics (North, 1990; Williamson, 1985). Tighter regulatory standards impose transition costs on incumbents (e.g., legal restructuring, renegotiation of contracts, and enhanced disclosure requirements). Still, the costs are outweighed by the long-term benefits like reduced systemic risk, less information asymmetry, improved investor protection, and enhanced market integrity (AAOIFI, 2025; Safutra, 2026). This is supported by the experience of other financial regulatory reforms, like Basel III capital requirements, where compliance costs first increased but eventually improved the resilience of the banking system (BCBS, 2017).

P4: Sectoral Applicability Proposition (Supplemental)

This proposition is based on agency theory (Jensen & Meckling, 1976). Where cash flows are inherently uncertain (e.g., in agriculture where climate risk exists, or in SMEs where market volatility exists), fixed-debt financing generates moral hazard, misaligned incentives and financial distress. Risk-sharing models that satisfy all three pillars align the interests of the financier and the entrepreneur, incentivize active monitoring and enable loss absorption during downturns (Khan, 2019; Ibrahim & Alenezi, 2024). This proposition extends the framework to other developmental finance applications besides banking.

Summary of Propositions

Proposition	Focus	Key Relationship Tested
P1	Trust & Legitimacy	Islamicity → Higher stakeholder trust
P2	Financial Resilience	Asset-backed (A) + Risk-sharing (R) → Lower default/volatility
P3	Regulatory Impact	AAOIFI Standard 62 → Short-term costs → Long-term stability
P4	Sectoral Applicability	Three-pillar framework → Better SME/agriculture outcomes

Operationalization for Future Research

To facilitate empirical testing, we recommend that researchers operationalize each pillar as follows:

Pillar 1 (E): Measured using a *Maqāṣid Compliance Index* that evaluates contract documentation against five dimensions: protection of faith, life, intellect, lineage, and wealth. This can be scored by independent Shariah reviewers (cf. El-Halaby & Hussainey, 2015).

Pillar 2 (A): Measured using an Asset Ownership Depth Score that assesses: (i) whether legal title is transferred; (ii) the duration of ownership; (iii) whether the financier bears maintenance, insurance, and depreciation risks; and (iv) the extent of recourse to the obligor in case of asset impairment.
Pillar 3 (R): Measured using a Risk-Sharing Coefficient, defined as:

$$R = 1 - \frac{\text{Guaranteed/ Fixed Return Component}}{\text{Total Expected Return}}$$

Where R = 1 refers to full risk-sharing (fully variable, performance-linked returns) and R = 0 refers to full risk-transfer (fully fixed returns similar to conventional debt).
These operationalizations allow researchers to build an aggregate Islamicity Score (E × A × R) for any given product or portfolio, and thus to statistically test the propositions above.

Conclusion of Propositions
The propositions are the conceptual framework translated into testable hypotheses to be investigated through quantitative and qualitative methodologies. P1: Stakeholder perception and market legitimacy, P2: Financial resilience and stability, P3: Regulatory dynamics and market evolution, P4: Sectoral applicability and developmental impact. Together they offer a complete research agenda to empirically validate (or invalidate) the framework put forward in this paper. Future researchers are hoped to test these propositions across various jurisdictions, asset classes and time periods to build a robust evidence base for the substantive practice of Islamic finance.

4. Discussion of Implications

Implications for Theory
Our framework offers a more complete and integrated theory of Islamic debt. It moves away from listing rules separately and instead demonstrates the structural and functional links between ethical foundations, asset-backed structuring, and risk-sharing mechanisms. By conceptualizing these three pillars as mutually reinforcing and non-fungible (Islamicist = E × A × R), the framework explains why Islamic finance often fails to meet its normative goals: because it implements the rules in isolation—treating legal compliance as sufficient—rather than as an integrated system where each pillar depends on the others for substantive authenticity.

This framework also positions Islamic finance as a useful model for all ethical finance, not merely for Muslim-majority contexts. The principles that finance should serve the real economy, that risk should be shared rather than transferred, and that contractual relationships should embody justice and transparency are universal values. They offer important lessons for reforming global finance, which is still marked by excess leverage, speculative bubbles and systemic instability (Askari et al., 2012; Stiglitz, 2010). This paper contributes to the wider literature on sustainable finance, ESG investing and stakeholder capitalism by demonstrating how these principles can be operationalized in a coherent framework.

The framework also advances the study of *maqāṣid* by moving beyond abstract moral appeals to measurable, contract-level standards. It translates the higher objectives of Islamic law (*maqāṣid al-Sharīʿah*) into concrete, measurable dimensions of asset ownership depth and risk-sharing coefficients, thus bridging the gap between normative theory and positive analysis.

Implications Product Development Practical Checklist
This framework is a practical step-by-step checklist for the design and evaluation of Islamic financial products for bankers, product developers and Shariah advisors. When practitioners are planning a new product or reviewing an existing one, they need to ask three fundamental questions:
Pillar 1 (Ethics): Does the contract satisfy the higher ethical objectives of Shariah (*maqāṣid*), or does it only meet formal legal requirements? Is it fair and transparent?
Pillar 2 (Asset-Backing): Does the bank truly own the underlying asset and bear its entire liabilities, including maintenance, insurance, depreciation and destruction risk, or is ownership only constructive and ephemeral?
Pillar 3 (Risk Sharing): Is the return of the financier tied to the actual performance of the asset/enterprise or is it a fixed predetermined payment like conventional interest?

If any of these questions receives a negative or qualified answer, the product fails the framework and should be redesigned or discontinued, regardless of its Shariah board approval.

Summary of Implications

In summary, this section has demonstrated the broad implications of the three-pillar framework. Theoretically, it offers an integrated model that moves beyond fragmented analyses and positions Islamic finance as a model for ethical finance globally. Practically, it provides a checklist for product developers, a basis for Shariah board accountability, and a rationale for regulatory reform—while also identifying key real-world disincentives that must be addressed for successful implementation. Empirically, it offers a rich agenda with operationalized variables and testable propositions. Finally, we have acknowledged the framework's limitations, particularly its conceptual nature, legal heterogeneity, interpretive diversity, and scope constraints. These limitations are not fatal but rather point to fruitful avenues for future research and refinement.

5. Conclusion and Recommendations

Summary of Contribution

This paper addresses the critical gap between the normative ideals and operational realities of Islamic finance. We have constructed a simple but powerful conceptual framework that organizes Islamic debt principles into three integrated pillars: Ethical Grounding (Pillar 1), Asset-Backed Structuring (Pillar 2) and Risk-Sharing Mechanisms (Pillar 3). We have demonstrated that these pillars are interdependent and non-fungible; authentic Islamic debt requires all three to be present simultaneously. If any pillar is missing or significantly weakened, the financing becomes structurally conventional, regardless of its Shariah documentation or legal form.

The framework contributes to theory by synthesizing Islamic jurisprudence with financial economics into a unified evaluative lens. It informs policy by providing a clear rationale for regulatory reforms, such as capital carve-outs for genuine PLS assets, that could encourage risk-sharing and enhance systemic stability. Finally, the framework links Islamic finance with wider global trends in ESG investing and sustainable development, thus placing Islamic finance as a legitimate and relevant player in the transition to ethical and responsible capitalism.

Final Word

Islamic finance has enormous potential to contribute to building a fairer, more stable and more sustainable global economy. Its fundamental principles - the prohibition of interest, asset-backing, and risk-sharing - are not merely religious injunctions but universal lessons for reforming a financial system mired in excessive leverage, speculation, and inequality. But this potential will be unlocked only if the industry stays true to its values. The three-pillar framework provides a clear map for that journey: by promoting ethics, real assets and collective risk, Islamic finance can provide a pragmatic and credible alternative to the debt-based, speculative model that dominates the world today. The transition will not be easy and will require a sustained commitment from regulators, practitioners and scholars alike. But the alternative is to continue down the path of form without substance, which risks making the industry irrelevant, a mere “Islamic finance in name only” (El-Gamal, 2006). The choice is clear and it is time to act now.

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Development and Pilot Validation of an Instrument Measuring Generation Z's Behavioral Intention Towards Festival Events

*Ayu Rohaidah Ghazali[1], Wan Soraya Wan Abdul Ghani[1], Nurakmal Ramli[1], Norhidayah Mohd Rashid[1], Nini Hartini Asnawi[1], Syazwani Mohamad[2], Muhammad Hafizuddin Mohamad Nazer[3]
[1]Faculty of Business & Management, Universiti Teknologi MARA, Malaysia
[2]Pasir Salak Community College, Perak, Malaysia
[3]Media Prima Berhad, Malaysia
Email: *ayuroh2956@uitm.edu.my, wansor2956@uitm.edu.my, nurakm2956@uitm.edu.my, norhidayah_rashid@uitm.edu.my, niniha3000@uitm.edu.my, syazwani@kkpsa.edu.my, hafizuddn.nazer@mediaprima.com.my
Corresponding Author: Ayu Rohaidah Ghazali

Abstract: Generation Z has become an important consumer segment in the festival industry; therefore, there is a need to develop a reliable instrument to measure the factors influencing their behavioral intention towards festival events. The study aimed to design and conduct a preliminary validation of a measurement instrument comprising four constructs: media influence, social interaction, festival image, and behavioral intention. A quantitative pilot study was conducted with 36 Generation Z respondents, and the data were analyzed using descriptive statistics and Cronbach's Alpha. The results revealed satisfactory internal consistency for all constructs (α = 0.864-0.933), indicating that the proposed instrument is reliable and suitable for future large-scale empirical investigations. The validated instrument provides a methodological base for future research on Generation Z festival behavior.

Keywords: *Festivals, Gen Z, Behavioral Intention, Media Influence, Festival Image, Instrument Development, Pilot Study, Measurement Validation*

1. Introduction and Background

The growth of the experiential economy has turned festivals from entertainment-based activities into important platforms for cultural engagement, social interaction, and identity development. Festivals have become increasingly prominent within contemporary tourism and leisure, generating economic, tourism and sociocultural benefits for destinations and communities (Collins & Potoglou, 2019). This growing relevance is particularly evident among Generation Z, for whom festivals have become an important leisure and tourism activity (Iványi, 2021). Generation Z, as digital natives, actively utilises social media to seek information, share experiences, and express their identities during festivals, making digital engagement an integral part of the overall festival experience (Hyun et al., 2025; Stanković et al., 2025). The decisions to participate are influenced by multiple variables, including media influence, social interaction, and festival image (Dunne et al., 2023; Iványi, 2021; Stanković et al., 2025).

Recent studies have indicated that Generation Z prefers festivals that offer authentic, engaging, and technology-enhanced experiences while encouraging meaningful social interaction and digital participation (Das et al., 2026; Wang & Iahad, 2025). Social media, influencer marketing and digital platforms are important for influencing festival image, evaluating event quality and influencing behavioural intentions among younger consumers (Alexandra & Choirisa, 2024; Arıcı & Eker, 2026; Na & Zakaria, 2024; Seyfi et al., 2024; Söderlund-Strand & Robertson, 2020; Swandewi et al., 2025).

The relationships between media influence, social interaction, festival image and behavioral intention have been studied in the setting of tourism and event research, but these constructs have primarily been examined in specific contexts such as residents' perceptions, destination image, revisit intention or social media marketing, rather than an integrated measurement framework for festival attendees (Li et al., 2018; Li et al., 2021; Fong et al., 2025). However, the development and validation of an integrated measurement instrument to assess Generation Z's behavioral intention towards festivals has received little attention (Fong et al., 2025).

Existing measurement instruments have largely been adapted from tourism, hospitality and consumer behavior research with relatively limited attention paid to developing and validating measurement scales

specifically for festival experiences and Generation Z. There are a few studies that have developed and validated measurement instruments in tourism and festival contexts. Nevertheless, the instruments were developed for different settings and populations, indicating that validation in the specific context is needed before being applied to Generation Z festival attendees in Malaysia (Olivier et al., 2023; Homer & Kanagasapathy, 2024).

Considering the increasing relevance of Generation Z as an important segment of festival consumers, a valid and context-specific measurement instrument is necessary before conducting large-scale empirical research. Hence, the objective of this research is to develop and preliminarily validate a scale of Generation Z's behavioural intention towards festivals and special events in a pilot study. The validated instrument will be a reliable tool for researchers and practitioners to use in future empirical investigations in the festival and event context. This study contributes to the literature by providing a reliable and contextually validated measurement instrument that can be used to facilitate future research on Generation Z behavioural intention towards festival events, particularly within the Malaysian context.

Research Objectives:

- To examine the internal consistency and reliability of the proposed measurement instrument through a pilot study involving Generation Z respondents.
- To provide a validated instrument for future empirical investigations on festival participation among Generation Z.

2. Literature Review

Festival Events

According to Chen and Yu (2024), a festival is defined as community-based, periodic events that celebrate themes such as cultural, religious, artistic, or recreational activities while offering immersive experiences for participants. Festivals as an important component of the experience economy, create meaningful social, cultural and emotional experiences that enhance visitor satisfaction and encourage behavioural intentions (Ambalika et al., 2025). The quality of the programme, onsite facilities, and Fear of Missing Out (FOMO) are identified as important factors affecting attendance, satisfaction, and revisit intention, especially among the younger generations (Ho et al., 2022; Sriwanna & Meeprom, 2026; Tan et al., 2023).

Modern festivals have evolved from one-off events into the use of interactive and digital platforms to enhance visitor engagement before, during and after the event (Stoleriu et al., 2023; Fernandes & Krolikowska, 2022). Moreover, memorable experiences, visitor satisfaction and long-term loyalty are achieved through festival experiences including entertainment, social interactions and personal enjoyment, along with tangible and intangible attributes of the event (Darvishmotevali et al., 2022; Erhan & Bangun, 2024; Gómez et al., 2021).

In Malaysia, festivals play a significant role in promoting tourism through the dissemination of cultural heritage and the attraction of local and foreign tourists (Tan et al., 2020). The sustainability of festivals and their contribution to tourism, community development, and the national economy have been further strengthened by government support, strategic marketing, and effective event management (Ghazali et al., 2025; Abhirami & Vineeth, 2025; Abu Talib et al., 2024). While major commercial gatherings such as the Good Vibes Music Festival demonstrate how modern events attract younger demographics while supporting local economic development (Abu Talib et al., 2024; Goh & Teh, 2022), there is an increasing prominence of uniquely Malaysian Gen Z–driven, grassroots cultural phenomena. A prime example is *Keretapi Sarong*, a viral public transport flash mob that evolved into a national Malaysia Day tradition where thousands of youth dress in traditional sarongs, batik, and kain pelikat to board urban transit trains together (Rosli et al., 2022). This event serves as a real-world reflection of how traditional cultural preservation, digital media influence, and active youth social interaction converge in the contemporary Malaysian landscape, fostering community identity, intergenerational heritage transmission, and youth-led domestic tourism engagement.

Generation Z as Festival Consumers

Generation Z refers to those born between the mid-1990s and the early 2010s and is recognised as the first generation of true digital natives (Abdullah et al., 2024; Hoo et al., 2024). They have grown up in an era with almost universal internet access and fast-paced technology, and they are highly dependent on digital platforms

and social networks for communication, information search, and self-expression (Fauzi et al., 2022; Hassan et al., 2025). Content created by peers, online reviews, and social media activities strongly shape their perceptions of festivals and special events (Yoo & Lee, 2025).

As festival-goers, Generation Z looks for authentic, meaningful and immersive experiences that foster social interaction and personal expression (Subramaniam & Thuraiselvam, 2025). They are active content creators on platforms like Instagram and TikTok, making social media an important part of their overall festival experience (Prasanna & Priyanka, 2024; Tseng et al., 2024). Research also shows that authenticity, emotional engagement, and opportunities for content creation significantly influence their event preferences and participation decisions (Blaži, 2025; Nareswari & Ratnawati, 2025; Pentescu, 2023).

Moreover, Generation Z desires experiences that facilitate personal development, sustainability and technology-enabled participation such as smart tourism applications (Buhalis & Karatay, 2022). Their need for online platforms to meet emotional needs and satisfy peer validation is an indication of the increasing importance of the experience economy where the value of the event is influenced by online influence and personal experiences (Luo, 2025; Stanković et al., 2025). Therefore, event organizers should design authentic, technology-driven festival experiences that integrate both physical and digital engagement to meet the expectations of Generation Z (Iványi & Bíró-Szigeti, 2020; Orea-Giner & Fusté-Forné, 2023).

Behavioral Intention

Behavioral intention refers to an individual's willingness or intention to engage in a particular behavior and is widely recognized as an important predictor of subsequent behavior. In the festival context, behavioral intention may include the intention to attend, revisit, recommend or engage with a festival (Darvishmotevali et al., 2022; Gorgadze et al., 2021). Previous studies have shown that behavioral intention is associated with future attendance, revisit intention and positive word-of-mouth, reflecting participants' potential future engagement with festivals (Gorgadze et al., 2021; Hinek & Papp-Váry, 2024; Lamari & Bouslama, 2025). For Generation Z, behavioral intention may also extend to digital participation, sharing festival experiences and promoting events through social media (Zhu et al., 2024).

The Theory of Planned Behavior (TPB) provides a relevant theoretical foundation for understanding behavioral intention. TPB proposes that intention is determined by attitude, subjective norm and perceived behavioral control, which reflect individuals' behavioral, normative and control beliefs regarding a particular behavior (Ajzen, 2020; Hagger & Hamilton, 2025). The theory can also be extended by incorporating additional context-specific factors when these provide theoretically relevant explanations of behavioral intention.

Media Influence

Media influence is the ability of communication channels to shape individuals' perceptions, attitudes, and behaviours by delivering information and persuasive content (Singh et al., 2023). In the case of festivals, perceptions of event quality, image, and value of potential attendees before attending are affected by both traditional and digital media (Hu & Abdullah, 2026; Li et al., 2018; Setiawan et al., 2022). Digital channels are particularly relevant for Generation Z, who rely heavily on Instagram, TikTok and other social media channels for festival information and are strongly influenced in their decisions to attend (Abdul Jabar et al., 2024; Lamari & Bouslama, 2025).

Influencer marketing, online reviews and content created by users further enhance media influence by providing social validation and electronic word-of-mouth that enhance trust, engagement and behavioural intention (Di Dalmazi et al., 2024; Salmiah et al., 2024; Tarigan et al., 2026; Zollo et al., 2021). An example of festivals in Malaysia is the Rainforest World Music Festival that has proved influencer marketing can raise awareness of the event and encourage the younger audience to join the event (Mandagi & Aseng, 2021).

From a TPB perspective, such media exposure may contribute to the formation of behavioral beliefs by providing information and persuasive cues that shape individuals' evaluations of festival participation. Therefore, positive and credible media content may contribute to more favorable attitudes and stronger behavioral intentions towards festival attendance. Festival organizers should consequently encourage participants to share their experiences through digital platforms, as user-generated content can strengthen

awareness, engagement and longer-term festival relationships (Habachi et al., 2024; Mandagi & Aseng, 2021; Putra, 2025).

Social Interaction

Social interaction is the process through which people exchange information, share experiences, and develop a sense of belonging within a social group. In the context of festivals, interactions among visitors, event crews, and companions contribute to memorable experiences, visitor satisfaction, and stronger emotional bonds (Li et al., 2025; Yin et al., 2023). Digital platforms also allow these interactions to be extended beyond the event itself, allowing participants to maintain relationships and engage with festival communities before and after the event (Barbe et al., 2020; Wang et al., 2024).

Previous studies suggest that social interaction strengthens social capital by promoting cooperation, reciprocity, and a sense of community among festival participants (Koenig-Lewis et al., 2021; Wood & Kinnunen, 2020). Festivals also promote social and cultural inclusion through the gathering of diverse groups to share common experiences, thus encouraging social cohesion and community sustainability (Gradinaru, 2021; Hassanli et al., 2021; Quinn et al., 2021; Stevenson, 2021).

For Generation Z, social interaction extends beyond face-to-face communication to include digital engagement and online content sharing (Barbe et al., 2020). Within the TPB perspective, social interaction can be primarily associated with normative beliefs and subjective norms. The preferences, approval and participation of friends and peers may create social expectations regarding festival attendance, while opportunities to participate with others may strengthen the perceived social value of attending.

Thus, social interaction provides a contextual basis for understanding how peer influence, social validation and opportunities for shared experiences may contribute to Generation Z's behavioral intention. Providing opportunities for peer interaction and digital participation may therefore encourage future engagement, repeat attendance and positive word-of-mouth (Li et al., 2025; Mandagi & Aseng, 2021; Salmiah et al., 2024; Sirianni & Sabbagh, 2020; Wang et al., 2024).

Festival Image

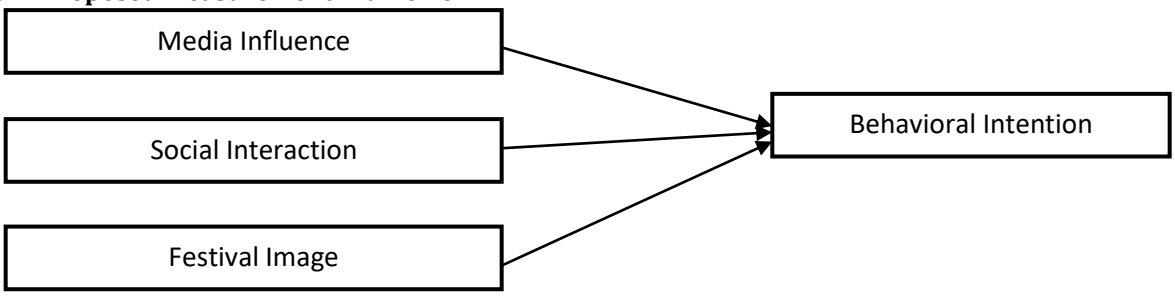
Festival image refers to visitors' overall perceptions and evaluations of a festival, shaped by cognitive and emotional reactions to the event (Chen & Yu, 2024). The positive image of a festival improves the perceived quality, authenticity, and emotional attachment, leading to increased visitor satisfaction, loyalty, and behavioural intentions (Supriono & Yulianto, 2021). Previous studies have shown that high-quality programs, physical facilities and authentic cultural experiences are important in creating a favourable image of the festival and enhancing visitors' emotional connection with the event (Chen & Yu, 2024; Supriono & Yulianto, 2021).

From a TPB perspective, festival image can be related to behavioural beliefs and the formation of attitude towards festival participation. A favourable image based on perceptions of quality, attractiveness, authenticity and uniqueness may lead individuals to form more positive evaluations of attending the festival, which may subsequently contribute to stronger behavioural intention. In addition to influencing the event experience, festivals can contribute to destination branding through the promotion of local culture and the attraction of domestic and international visitors (Abou-Shouk et al., 2024; Amorim et al.,2020).

The Malaysian government has also used cultural festivals to reinforce the country's tourism image and promote tourism development through initiatives such as the Malaysia Truly Asia campaign (Ayob, 2003). Festivals can further contribute to regional economic development through cultural heritage preservation and the encouragement of year-round tourism activities (Yalçınkaya & Çaylan, 2026).

Unlike one-off special events, festivals are recurring and culturally embedded, allowing organizers to build stronger emotional connections and longer-term relationships with visitors (Supriono & Yulianto, 2021). Maintaining a positive festival image through authentic cultural experiences and effective event management is therefore important in strengthening positive evaluations, repeat attendance, visitor loyalty and behavioural intentions.

Figure 1: Proposed Measurement Framework



3. Research Methodology

This study employed a quantitative pilot survey to develop and conduct a preliminary validation of a measurement instrument assessing the behavioural intention of Generation Z towards festival events. The questionnaire was developed based on a thorough review of the literature and comprised four primary constructs: Media Influence, Social Interaction, Festival Image, and Behavioural Intention. Measurement items were adapted from established scales and refined to suit the Malaysian Generation Z context. All items were measured on a five-point Likert scale. Before distribution, the questionnaire underwent expert review to establish content validity (Connelly, 2008).

Data collection for the pilot study was conducted online using a self-administered web-based survey distributed across a university campus. A convenience sampling technique was employed, targeting Generation Z students who had experience attending local festival events. The digital survey link was disseminated through online campus platforms and student messaging channels. Screening questions were embedded at the start of the questionnaire to verify that respondents belonged to the Generation Z segment and had attended at least one festival before participating in a past event.

A total of 36 eligible Generation Z respondents completed the pilot survey. Data were analyzed using IBM SPSS Statistics. Descriptive statistics were utilized to provide an overview of respondent characteristics, while internal consistency reliability was evaluated using Cronbach's Alpha, with values of 0.70 or above considered acceptable (Hair et al., 2022). The findings were used to confirm the reliability and suitability of the instrument for future large-scale empirical research.

Figure 2: Development of Measurement Instrument

Construct	Operational Definition	Source of Measurement Items	No. of Items	Adaptation
Media Influence	The extent to which digital media, social media platforms, online reviews, and promotional content influence Generation Z's perceptions and intention to attend festivals and special events.	Li et al. (2018); Kwok et al. (2017)	7	Adapted and modified to suit the Malaysian festival context.
Social Interaction	The degree to which opportunities for interaction, relationship building, and shared experiences with family, friends, and other festival attendees influence participation intention.	Wang et al. (2024); Li et al. (2025); Barbe et al. (2020)	7	Items adapted to reflect festival-based social experiences among Generation Z.

Construct	Operational Definition	Source of Measurement Items	No. of Items	Adaptation
Festival Image	Overall perception of the attractiveness, uniqueness, quality, and reputation of a festival that shapes visitors' evaluation and intention to participate.	Koo, Byon & Baker (2014); Kim et al. (2017); Chen & Yu (2024); Supriono & Yulianto (2021)	6	Items modified to capture the cognitive and affective image of festivals.
Behavioural Intention	The likelihood that Generation Z intends to attend, revisit, and recommend festivals and special events in the future.	Koo et al. (2014); Gorgadze et al. (2021); Lamari & Bouslama (2025)	7	Adapted to measure intention to participate in festivals and special events.

The measurement instrument was developed from an extensive review of the festival, tourism, event management and consumer behavior literature. This study combined measurement items from several validated studies to better capture the multidimensional nature of Generation Z's behavioral intention towards festival events. Several items were slightly modified in wording to ensure contextual relevance in the Malaysian festival industry while maintaining the original conceptual meaning of each construct.

4. Findings

Respondents' Profile

A total of 36 Generation Z respondents participated in this pilot study. The respondents comprised 29 females (80.6%) and 7 males (19.4%). Most respondents were aged between 22 and 23 years (58.3%), followed by 20–21 years (30.6%) and 24 years and above (11.1%). In terms of festival experience, the majority had attended more than 10 festivals or special events (33.3%), followed by 3–5 events (27.8%), 6–10 events (27.8%), and 1–2 events (11.1%) during the past two years. This indicates that the respondents possessed relevant festival experience and were considered appropriate participants for evaluating the proposed measurement instrument.

Table 1: Demographic Profile of Respondents (N = 36)

Variable	Category	Frequency	Percentage (%)
Gender	Male	7	19.4
	Female	29	80.6
Age	20–21 years	11	30.6
	22–23 years	21	58.3
	24 years and above	4	11.1
Festival Attendance (Past Two Years)	1–2 events	4	11.1
	3–5 events	10	27.8
	6–10 events	10	27.8
	More than 10 events	12	33.3

Reliability Analysis

Reliability analysis was conducted using Cronbach's Alpha to assess the internal consistency of the proposed measurement instrument. As presented in Table 2, all constructs exceeded the recommended threshold value of 0.70, indicating satisfactory reliability.

Table 2: Reliability Analysis of the Measurement Instrument

Construct	No. of Items	Cronbach's Alpha	Interpretation
Media Influence	7	0.864	Good
Social Interaction	7	0.871	Good
Festival Image	6	0.872	Good
Behavioural Intention	7	0.933	Excellent

Overall, the findings indicate that all constructs demonstrated satisfactory internal consistency, suggesting that the proposed measurement instrument is reliable and appropriate for use in the main study.

Descriptive Statistics

Descriptive statistics were performed to examine respondents' overall responses to the proposed measurement instrument. As shown in Table 3, all constructs recorded high mean scores, indicating positive responses and suggesting that the questionnaire items were clearly understood by the respondents.

Table 3: Descriptive Statistics of the Measurement Instrument

Construct	Mean	Standard Deviation	Interpretation
Media Influence	4.39	0.61	High
Social Interaction	4.14	0.71	High
Festival Image	4.34	0.60	High
Behavioural Intention	4.38	0.59	High

Overall, respondents reported high levels of agreement across all constructs, indicating that the proposed measurement instrument was appropriate, understandable, and relevant for measuring Generation Z's behavioural intention towards festivals and special events. The pilot study successfully achieved its objective of evaluating the preliminary reliability of the proposed measurement instrument. Prior to assessing scale reliability, data normality was evaluated by examining the skewness and kurtosis values for all construct items.

All values fell within the acceptable thresholds of ±2.0 for skewness and ±2.0 for kurtosis, confirming that the data satisfied the assumption of normal distribution (Hair et al., 2022). All constructs demonstrated satisfactory internal consistency, with Cronbach's Alpha values ranging from 0.864 to 0.933. In addition, all constructs recorded high mean scores, suggesting that respondents clearly understood the questionnaire items and responded consistently. These findings indicate that the proposed measurement instrument is reliable and suitable for future large-scale empirical research involving Generation Z.

5. Managerial Implications and Recommendations

The findings have practical implications for festival organizers and tourism stakeholders. The strong influence of media, social interaction and festival image suggests that participation not only depends on the event program but also on how festivals are communicated, experienced and perceived.

Festival organizers should strengthen digital and social media strategies through engaging short-form content, behind-the-scenes materials, attendee testimonials and user-generated content to build awareness, credibility and anticipation. Moreover, organizers should incorporate social interaction into event design through group activities, interactive installations, social spaces and collaborative experiences that encourage Generation Z to attend and participate with friends. Event organizers should also create a clear and consistent festival image across all promotional communication and the actual event experience. Branding, entertainment, venue design and activities should reflect a distinctive identity that is relevant to Generation Z.

The findings also have implications for policymakers and tourism organizations such as Tourism Malaysia. The identified factors can be used for the development of youth-oriented festival strategies, promotional campaigns and support programs. Tourism stakeholders could use digital platforms and youth-focused content to position

Malaysian festivals as attractive social and experiential destinations for younger audiences. The measurement instrument could also be used as a baseline to gauge Generation Z's perceptions and intentions to participate in government-supported festivals and tourism events.

As this study represents a preliminary pilot validation, future research should test the instrument using larger and more representative samples and further examine factors such as perceived value, authenticity, event experience and satisfaction.

Conclusion

This study contributes to the event management literature by developing and preliminarily validating an integrated measurement instrument for assessing Generation Z's behavioral intention towards festival events. The pilot findings indicate the instrument had good internal consistency and provided preliminary evidence for the instrument being appropriate for further large-scale empirical investigations.

The instrument provides researchers and practitioners with a framework for examining the evolving preferences and participation behavior of Generation Z in the current festival context. Additionally, given the preliminary nature of the validation process it provides opportunities to identify possible inadequacies in measures used to capture constructs and the structure of the instrument prior to their application at large scales.

Further studies are needed to fully establish the validity of this instrument through larger and more diverse samples within different contexts and festivals. A pre-validated instrument reduces the chances of making structural and measurement errors when embarking upon high-budget and nationally significant research initiatives into festival events in Malaysia.

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Redefining Human Capital Sustainability: An Integrative Conceptual Framework Harmonizing ISO 45003 and the Job Demands-Resources Model for Psychosocial Risk Assessment

*Faizatul Akmam Amirrudin[1], Norina Ahmad Jamil[1], Mashitah Mohamed Esa[1], Faizah Mashahadi[1], Nurul 'Ain Amirrudin[2]
[1]Faculty of Business and Management, Universiti Teknologi MARA, Selangor, Malaysia
[2]Faculty of Information Sciences and Engineering, Management and Science University, Selangor, Malaysia
Email: *akmamamir671@uitm.edu.my, norina0048@uitm.edu.my, mashitah9803@uitm.edu.my, faizahmashahadi@uitm.edu.my, nurulain_amirrudin@msu.edu.my
Corresponding Author: Faizatul Akmam Amirrudin

Abstract: Although Corporate Social Sustainability programs have matured and Environmental, Social, and Governance (ESG) frameworks have become institutionalized, organizations remain structurally under-prepared for the rising incidence of workplace burnout worldwide. This conceptual paper addresses a silo that has lingered at the intersection of Occupational Safety and Health (OSH) scholarship on one side and corporate sustainability reporting on the other: the absence of a defensible theoretical bridge between micro-level psychosocial risk management and macro-level human capital outcomes. We align the structural hazard taxonomy codified in ISO 45003 (International Organization for Standardization, 2021) with the dual-pathway psychological mechanics of the Job Demands–Resources(JD-R) model (Demerouti et al., 2001) and assemble a streamlined conceptual framework that treats systematic Psychosocial Risk Assessment (PRA) as the operational engine connecting structural hazard controls to quantifiable social sustainability indicators. Adjacent constructs drawn from Psychosocial Safety Climate (PSC), Effort–Reward Imbalance (ERI), Conservation of Resources (COR) theory, and the recovery-experiences literature are integrated into a single causal architecture anchored by a Core Proposition suitable as an entry-point hypothesis for new investigations. The contribution advances the JD-R model into the regulatory and corporate-governance vocabulary, and it extends ESG Social measurement beyond lagging demographic indicators toward leading, auditable risk scores. The framework is intended to function both as theoretical scaffolding for occupational health psychology researchers and as a strategic roadmap for chief human resource officers, boards, sustainability committees, and investor analysts.

Keywords: *Psychosocial risk, ISO 45003, Job Demands–Resources Model, Environmental, Social and Governance, human capital, social sustainability, burnout, Psychosocial Safety Climate, technostress, recovery experiences.*

1. Introduction

Modern corporations have spent decades refining algorithmic frameworks that protect physical capital and optimize financial assets. They have done far less for the resource that is simultaneously their most valuable and most exhaustible: human capital. Chronic occupational exhaustion — reclassified by the World Health Organization (WHO) in the 11th Revision of the International Classification of Diseases (ICD-11) as an occupational phenomenon rooted in chronic workplace stress that has not been successfully managed (World Health Organization, 2019) — has migrated from an individual psychological vulnerability into an institutional hazard whose financial consequences (voluntary turnover, absenteeism, presenteeism and elevated health-insurance claims) now hit the corporate balance sheet directly.

Recent regulatory moves have begun to shift the institutional response. The publication of ISO 45003 (International Organization for Standardization, 2021) marks a watershed moment in global corporate governance: psychosocial hazards-unmanageable workload velocity, role ambiguity, availability creep, interpersonal conflict, and inadequate managerial support are now formally elevated to the same operational and legal standing as physical, chemical, or ergonomic risks. By standardizing the conduct of Psychosocial Risk Assessments (PRAs) and demanding structural redesign of the work environment, ISO 45003 removes much of the ambiguity that previously allowed managers to treat chronic strain as a private, non-auditable matter. The standard sits squarely within the management-system architecture already established by ISO 45001.

A persistent disconnection remains, however. Occupational Safety and Health (OSH) scholarship continues to treat psychosocial risk as a localized compliance task managed by human resources or safety functions.

Corporate sustainability literature, by contrast, evaluates the "Social" pillar of Environmental, Social, and Governance (ESG) reporting through lagging, demographic-style indicators diversity ratios, headcounts, aggregated injury-frequency data that are detached from the everyday operational stress profiles of the workforce (Bautista-Bernal et al., 2021). The two literatures share the construct of "worker well-being" but communicate through incompatible measurement vocabularies. There is, accordingly, a clear theoretical and operational demand for an integrative framework that connects the micro-dynamics of daily psychosocial risk exposure with the macro-imperative of corporate human sustainability.

The paper develops such a framework. Drawing upon the dual-pathway psychology of the Job Demands–Resources (JD-R) model (Bakker & Demerouti, 2016; Demerouti et al., 2001), the upstream organizational climate literature on Psychosocial Safety Climate (PSC) (Dollard & Bakker, 2009; Dollard & McTernan, 2011), the social-exchange conceptualization of Effort–Reward Imbalance (ERI) (Siegrist, 1996, 2010), the motivational stress logic of Conservation of Resources (COR) theory (Bon & Shire, 2022; Liao et al., 2021), the recovery-experiences tradition (Fritz et al., 2010; Sonnentag & Fritz, 2007), and the empirical body of technostress research (Tarafdar et al., 2007, 2010), we propose a structural intervention model in which ISO 45003-aligned PRAs function as the upstream lever that simultaneously dampens the health-impairment pathway and reinforces the motivational pathway of the JD-R model, thereby driving macro-level human-capital sustainability outcomes.

Three central objectives structure the remainder of this paper. First, we map the conceptual contribution against the existing psychosocial-risk and sustainability literature. Second, we synthesize the JD-R model with adjacent psychosocial frameworks, operationalize ISO 45003 as an audit-ready taxonomy for the social pillar of ESG disclosure, and assemble these inputs into a single parsimonious theoretical framework anchored by a Core Proposition. Third, we position the framework against broader implementation and methodological opportunities that will guide future empirical work.

2. Literature Review and Positioning of the Contribution

Bibliometric and Theoretical Positioning

Bibliometric evidence points to a sizeable but fragmented intersection between Occupational Safety and Health (OSH) management research and the social-responsibility/sustainability literature (Bautista-Bernal et al., 2021). The transition from OHSAS 18001 to ISO 45001 produced smooth organizational handovers in many firms, but the incorporation of psychosocial risk into the OSH management system has lagged partly because of the absence of a structured, risk-based language equivalent to the "hazard–exposure–control" vocabulary that physical-safety practitioners take for granted. Recent scholarship confirms that the lack of competent personnel, employee fear of disclosure, and methodological unfamiliarity constitute the principal barriers to systematic psychosocial-risk management under ISO 45003 (Wierzowiecka, 2022), and practitioners continue to call for management-system architecture that explicitly incorporates well-being alongside traditional safety (Boyle & Charlton, 2024).

Within occupational health psychology, the JD-R model is the most widely cited theoretical framework for understanding occupational strain (Bakker & Demerouti, 2007; Demerouti et al., 2001). Its empirical reach has been extended in several directions: personal resources (Bakker et al., 2022), multilevel and proactive behavior extensions (Bakker et al., 2022), and recovery-experience mediators (Kinnunen et al., 2011). PSC literature has pushed JD-R upward, identifying senior management values as the upstream antecedent of workplace demands and resources (Dollard & Bakker, 2009; Dollard & McTernan, 2011; Mansour & Tremblay, 2019). ERI literature has verified the cardiovascular and mental-health consequences of perceived imbalance between effort and reward (Backé et al., 2011; Fishta & Backé, 2015; Siegrist, 1996, 2010). COR has supplied the motivational-stress scaffolding that explains why resource loss dominates resource gain in determining strain (Becker et al., 2019; Bon & Shire, 2022; Liao et al., 2021). The technological transition has produced an independent strand of research on technostress, whose creators (techno-overload, techno-invasion, techno-complexity, techno-uncertainty, techno-insecurity) are now empirically documented as predictors of role stress, exhaustion, and reduced ICT-mediated productivity (Tarafdar et al., 2007, 2010, 2014). The recovery-experiences tradition, lastly, has shown that psychological detachment, relaxation, mastery, and control during off-work time act as restorative mechanisms that moderate the transition from demands to strain (Fritz et al., 2010; Kinnunen et

al., 2011; Sonnentag & Fritz, 2007).

What the reviewed literature lacks is an integrative cross-walk between ISO 45003 and these traditions. The present paper responds to that gap.

Theoretical Contribution Statement

Three advances distinguish this paper from prior work. First, to the authors' knowledge, it offers the first systematic alignment of the JD-R model with the ISO 45003 three-domain structure, grounding the integrated framework in the dual-pathway psychology articulated by Demerouti et al. (2001) and Bakker and Demerouti (2016). Second, it explicitly integrates PSC, ERI, COR, and recovery-experiences theory as compatible rather than competing lenses through which to interpret the framework's buffering logic. Third, it formalizes the bridge to ESG Social indicator auditing, treating PRA scores as prospective leading indicators rather than retrospective compliance artefacts.

Theoretical Background

The Core Mechanics of the JD-R Model

The JD-R model posits that, irrespective of industry or occupation, every occupational characteristic can be sorted into one of two overarching categories: Job Demands and Job Resources (Bakker & Demerouti, 2007; Demerouti et al., 2001).

Job Demands are those physical, psychological, social, or organizational aspects of the job that require sustained physical and/or psychological effort and that carry corresponding physiological and psychological costs, such as chronic fatigue and cognitive exhaustion. The demands divide into quantitative forms, such as workload and time pressure, and qualitative forms, such as role conflict and emotional dissonance. When recovery opportunities are inadequate, the same regenerative resource pool is taxed repeatedly rather than replenished, and adverse effects accumulate across both the working week and the longer working life.

Job Resources are those physical, psychological, social, or organizational aspects of the job that are functional for achieving work goals, for reducing job demands and their associated physiological costs, or for stimulating personal growth, learning, and development. They divide into operational resources such as tools and training, which enable a task to be completed with less wasted effort; relational resources such as supervisor support and team cohesion, which provide the interpersonal scaffolding on which task work rests; and organisational resources such as procedural justice and career prospects, which shape the procedural and developmental conditions under which work takes place (Bakker & Demerouti, 2016; Demerouti et al., 2001).

The interaction of Job Demands and Job Resources initiates two distinct psychological pathways that determine workforce sustainability: the health-impairment pathway and the motivational pathway (Bakker & Demerouti, 2016; Demerouti et al., 2001). On the health-impairment pathway, chronic and unrecovered demand exposure drains available energy and erodes cognitive and physiological reserve. Where resources are insufficient to buffer it, the trajectory continues to clinical burnout, psychosomatic illness, and, at the limit, organisational exit. On the motivational pathway, robust resources foster engagement, intrinsic motivation, and organisational commitment by satisfying the basic psychological needs of autonomy, competence, and relatedness. They also buffer the conversion of demands into strain, so that the cumulative depletion on which the first pathway depends is materially reduced.

The Buffering Hypothesis

Bakker et al. (2004) reported that the buffering hypothesis is not universally supported empirically; their performance-outcome test found strong support for the direct routes but not for the demand × resource interaction on exhaustion. That honesty matters for the framework developed here: the resource-buffering strand is therefore specified as a moderated relationship whose magnitude, rather than direction, is the target of empirical test. Buffering should be expected more reliably when resources are operationalized at the structural rather than individual level and particularly where the resources activate recovery experiences.

Personal Resources

Bakker et al. (2022) emphasize the person × situation dynamic and the integration of personal resources (optimism, self-efficacy, resilience) with job resources. Personal resources parallel job resources in motivational function; they operate in tandem with, but do not substitute for, structural job resources. For organizational-level analysis — the natural unit of ISO 45003-PRA — the actionable variables remain the job-level resources; personal resources enter the framework as covariates or boundary conditioners rather than primary levers.

Gain and Loss Spirals

COR theory's first principles — primacy of resource loss, loss and gain spirals, and resource caravans (Bon and Shire, 2022; Liao et al., 2021) — supply the dynamic logic explaining why chronic demand exposure escalates disproportionally. A worker who enters a high-demand week with a depleted resource caravan spirals quickly into exhaustion; a worker with a robust caravan absorbs the same demand with greater resilience. The implication for ISO 45003-PRA design is that structural interventions targeting resources are most consequential when they replenish depleted caravans rather than merely provision marginal increments to already-buffered workers.

The Engagement–Burnout Continuum

Schaufeli and Bakker (2004) applied multi-sample structural equation modelling (N = 1698) and showed that burnout is principally predicted by job demands but also by a shortage of job resources, while engagement is predicted only by the resources actually available. Bakker et al. (2014) consolidated this finding into a dual-process model in which burnout and engagement sit as antithetical but not perfectly inverse; across typical samples the two poles share between 10 and 25 per cent of their variance. The practical consequence is that any structural control which reduces exhaustion also feeds the motivational pathway in parallel, so the two processes cannot be managed sequentially as if they were independent.

Burnout, the WHO ICD-11 Framing, and the Engagement Continuum

Burnout has migrated from a clinically debatable construct to an internationally codified occupational phenomenon under the World Health Organization (WHO) ICD-11 framework (World Health Organization,2019), but the codification has not displaced the consensus measurement architecture. The Maslach Burnout Inventory – General Survey (MBI-GS) remains the canonical instrument, organised around the three dimensions of exhaustion, cynicism, and professional efficacy. Schaufeli (2017) traces how JD-R research has, in parallel, validated the Utrecht Work Engagement Scale (UWES) as the canonical metric for the motivational counterpart. MBI-GS is consequently retained for health-impairment-pathway outcomes and UWES for motivational-pathway outcomes, on the principle that each instrument pairs with the outcome it was theoretically designed to detect.

Adjacent Psychosocial Frameworks

Job Demands–Control Tradition

The earlier Job Demands–Control (JF-C) family and its Job Demands–Control–Support (JD-C-S) extension constitute JD-R's conceptual parentage. Bakker and Demerouti (2007) explicitly position JD-R as the more flexible descendant, capable of integrating occupational features that the binary control dimension in the JD-C lineage could not accommodate. ISO 45003 Domain 1, which addresses work organisation including control and autonomy, is directly congruent with the JD-Control axis; ISO 45003 Domain 2, which addresses social factors, carries forward the JD-C-S support dimension. For senior management accustomed to the older vocabulary, JD-C and JD-C-S supply the historical legitimacy and intelligibility on which JD-R sits as the integrative umbrella.

The Effort–Reward Imbalance (ERI) Model

ERI focuses on the reciprocity contract between sustained effort and the rewards received in return, distinguishing three reward dimensions: money, esteem, and promotion/security (Siegrist, 1996). The cardiovascular and mental-health consequences of imbalance are now well established across systematic reviews (Backé et al., 2011; Fishta & Backé, 2015), and Siegrist (2010) further consolidated the empirical base. Kivimäki et al. (2007) examined whether ERI is redundant with procedural and relational injustice and found the constructs complementary rather than substitutable. For the present framework, ERI maps most naturally

onto ISO 45003 Domain 1 (under-reward signalling) and Domain 2 (procedural/relational justice dimensions). ERI's call for "intervention studies guided by this theoretical approach" (Siegrist, 2010) is precisely what ISO 45003 institutionalizes when adopted as a structural control mechanism.

Conservation of Resources (COR) Theory

COR theory positions resource loss as the primary engine of stress; resource gain assumes a secondary, less weighted role (Bon & Shire, 2022; Liao et al., 2021). For ISO 45003-aligned PRA, COR supplies the cumulative-erosion logic: each successive PRA cycle that identifies an unresolved resource deficit (low control, low support, persistent tech-friction) represents a marginal depletion of the organizational resource caravan. Becker et al. (2019) extend COR to ICT and email-monitoring expectations, finding that prolonged resource loss through attention depletion rapidly erodes well-being and bleeds into significant-other relationships — a particularly salient boundary condition for hybrid and remote workforces.

Psychosocial Safety Climate (PSC)

PSC refers to shared perceptions of organizational policies, practices, and procedures for the protection of worker psychological health and safety (Dollard & Bakker, 2010). Empirically, PSC operates as an upstream precursor of job-level demands and resources: senior-management values determine whether workers experience workload compression or workload regulation. Hall et al. (2010) developed the PSC-12 instrument with four sub-scales; Dollard and McTernan (2011) extended the model across multiple levels of analysis and documented the role of sector-level policy environments; Mansour and Tremblay (2019) demonstrated PSC's downstream impact on burnout and safety-workaround behavior in healthcare. For ISO 45003-aligned PRA, PSC functions as a domain-level antecedent: Domain 2 (managerial support, communication, voice) is the operational residue of a high-PSC organization, while a low-PSC organization will generate structural hazards faster than any combination of secondary-tier wellness interventions can absorb.

Recovery Experiences: A Missing Bridge in the Buffering Logic

The buffering hypothesis of the JD-R model rests on the assumption that resources either bracket demands cognitively or provide operational slack. The recovery-experiences tradition supplies a complementary mechanism: actions and mental states during off-job time that replenish depleted resources. Sonnentag and Fritz (2007) developed the Recovery Experience Questionnaire, measuring four dimensions: psychological detachment from work, relaxation, mastery, and control. Fritz et al. (2010) demonstrated that each recovery experience has a distinct and measurable association with affective states and exhaustion indicators; Kinnunen et al. (2011) tested recovery experiences as mediators in JD-R structural models and confirmed their theoretical and empirical explanatory value. The present framework proposes that buffers operate most reliably when workers can actually convert structural Domain 1 (control/autonomy) and Domain 2 (psychological safety) resources into recovery experiences during off-job time — a specification that strengthens the moderation claim by supplying a mechanism beyond mere statistical interaction.

Leadership Behaviors and the Social Domain

ISO 45003 Domain 2 explicitly incorporates leadership behaviors as part of the social climate. The transformational leadership tradition provides the most empirically supported case for the resource-amplification function of leadership behaviors, while servant leadership models extend the ethical-climate dimension under which PSC operates. Abusive supervision — the systematic expression of hostility by a manager toward subordinates — has been documented in the Organizational Behavior (OB) literature as a strong destructive demand. The paper does not generate new empirical results on leadership, but the framework should be read as embedding the proposition that MBI-GS trajectories will track the leadership construct layer of ISO 45003 Domain 2 directly, with service-sector and knowledge-work populations most acutely sensitive.

Cross-Cultural Validity of PRA Instruments

The cross-cultural validity of underlying PRA instruments is a substantive constraint on the generalizability of the framework. The Copenhagen Psychosocial Questionnaire (COPSOQ) family originated in Scandinavia and has been translated into more than twenty languages with documented reliability and factor-structure comparability (Schaufeli, 2017); the Health and Safety Executive (HSE) Management Standards Indicator Tool has been validated in British, Australian, and several European administrations (Bautista-Bernal et al., 2021);

MBI-GS and UWES have been translated and validated in dozens of languages with replicated factor structures; and PSC-12 has been validated across multi-occupational samples (Hall et al., 2010). Yet instrument equivalence in collectivist versus individualist cultural contexts, and across high-power-distance versus low-power-distance organizational hierarchies, remains unresolved at the metric level. The framework should therefore be deployed, where feasible, with parallel-form or back-translation protocols and with multi-group confirmatory factor analyses before drawing cross-jurisdictional inferences. This caveat is revisited in the Limitations section.

3. ISO 45003 as an Operational Taxonomy for the JD-R Model

The Three-Domain Structure

The JD-R model offers a robust diagnostic explanation of how burnout occurs, but it remains a relatively abstract framework that does not explicitly categorize the modern structural hazards an organization must audit. ISO 45003 (International Organization for Standardization, 2021) fills this void with a three-domain operational taxonomy that maps cleanly onto the demands–resources binary.

Table 1: Mapping of the ISO 45003 three-domain hazard taxonomy to the Job Demands–Resources binary

Domain	Demands	Resources
Domain 1: Work Organization	• Workload velocity • Role ambiguity • Lack of task control	• Job Control & Autonomy
Domain 2: Social Factors	• Low supervisor support • Toxic team dynamics • Workplace bullying	• Managerial support • Psychological safety • Transparent communication
Domain 3: Work Environment, Equipment & Conditions	• Availability creep • Tool friction • Ergonomic exposure	• Ergonomics • Usable interface • Digital-environment design

Domain 1 — How Work is Organized. ISO 45003 explicitly identifies workload velocity, role ambiguity, and lack of task control as primary psychosocial hazards. In JD-R vocabulary, workload velocity and role ambiguity are severe, energy-depleting job demands; the Domain 1 focus on task control is the operational supply side of a structural job resource. When an organization uses a PRA to optimize job design — for instance, by increasing worker autonomy, Domain 1 resource supply rises, structurally injecting a buffer that dampens the health-impairment pathway.

Domain 2 — Social Factors at Work. This domain covers interpersonal relationships, managerial support, and organizational culture. Within JD-R, low supervisor support, toxic team dynamics, and workplace bullying constitute destructive psychological demands; a workplace characterized by psychological safety and transparent communication supplies a high-value job resource. PRA evaluation of these social dynamics effectively audits the structural strength of an organization's motivational pathway.

Domain 3 — Work Environment, Equipment and Conditions. ISO 45003 addresses the physical and digital interfaces of labor: fragmented software systems, poor ergonomics, isolated remote work environments, and equipment-imposed pacing. In digitalized corporate environments, tech fatigue and constant availability expectations represent an evolved demand category that accelerates cognitive exhaustion. Domain 3 has, until recently, been under-instrumented in OH&S practice; the integrative framework's bridging logic addresses precisely this omission.

Integration with the ISO 45001 Management System

ISO 45003 is explicitly designed to operate within the management-system architecture established by ISO 45001 (Boyle & Charlton, 2024). Where ISO 45001 specifies the management-system plumbing (context of the organization, leadership and worker participation, planning, support, operation, performance evaluation, and improvement), ISO 45003 supplies the content of psychosocial-risk management that the management system must conduct (Boyle & Charlton, 2024; Wierzowiecka, 2022). A mature ISO 45001-compliant system can

integrate ISO 45003 without rebuilding its audit cycle; an organization lacking ISO 45001 maturity will need to lift its general systems discipline before PRA scores can be evidenced as audit-grade indicators.

Table 2: Procedural templates for Psychosocial Risk Assessment under ISO 45003: comparative orientation, empirical evidence, and principal contribution

Procedural Template	Methodological Orientation	Field Context & Empirical Evidence	Principal Contribution
Borodina et al. (2023)	Bowtie-based hazard decomposition; eight-step procedure (preparation → data collection → analysis → preventive-measure design → verification)	Ukrainian industrial enterprises; documented procedure design and post-intervention verification protocol	Hazard → consequence → control decomposition logic; explicit feedback loop from individual health assessments to structural intervention
Wierzowiecka (2022)	Barrier diagnosis in mature ISO 45001-compliant systems	Polish OH&S management literature; expert review of barriers encountered during psychosocial-risk integration	Taxonomy of implementation barriers: lack of competent personnel, fear of disclosure, methodological unfamiliarity
Nebbs et al. (2025)	Hybrid method pairing dedicated implementation teams with a facilitated planning process (adapted from health-guideline implementation science)	Six regional Australian organizations; 29 semi-structured interviews at two time points; three emergent themes	First peer-reviewed empirical demonstration of cross-site ISO 45003 feasibility; produced tailored implementation plans

Procedural Operationalization of PRA

Three procedural templates now exist in the published literature through which ISO 45003-PRA can move from specification to reproducible practice. Borodina et al. (2023) describe a Bowtie-based procedure for industrial enterprises in which preparation, data collection, and analysis are conducted against a structured hazard inventory, with explicit feedback from individual health assessments feeding into preventive-measure design; the procedure operates with eight core steps culminating in post-intervention verification. Wierzowiecka (2022) writing from a mature OSH system perspective, supplies the complementary implementation-barrier diagnosis — lack of competent personnel, employee fear of disclosure, and methodological unfamiliarity — that any adopter must navigate. Nebbs et al. (2025) add what the other two sources do not yet provide: empirical feasibility evidence. Across six regional Australian organizations, their hybrid method — implementation teams combined with a facilitated planning process adapted from health-guideline implementation — produced tailored, evidence-informed implementation plans at every site despite organizational variation. Triangulating industrial Bowtie decomposition (Borodina et al., 2023), barrier diagnosis in mature OSH systems (Wierzowiecka, 2022), and team-based facilitated implementation in six surveyed sites (Nebbs et al., 2025) establishes that ISO 45003 can be operationalized across diverse contexts, and supplies the empirical anchor for the audit-grade assumption that underwrites the Core Proposition advanced in Section 4.

From PRA to ESG: Closing the Social Measurement Gap

The "Social" component of ESG disclosure has historically relied on lagging, descriptive indicators: gender split, nationalities represented, lost-time injury frequency rates, voluntary turnover statistics gathered after the separations have occurred. Prior literature establishes that high-sustainability firms exhibit distinct governance and performance characteristics, and existing scholarship documents that ESG-oriented investing can produce measurable financial returns. These findings reinforce the strategic importance of the Social pillar, but neither furnishes a leading operational indicator of the Social pillar's underlying quality. Existing

scholarship further reports that credible Social performance metrics are predictive of subsequent financial outcomes — yet the operational indicators remain detached from the day-to-day operational stress profile of the workforce.

ISO 45003 changes the calculus. The standard does for psychosocial stress what OHSAS 18001/ISO 45001 did for physical safety: it specifies a standardized, repeatable, auditable assessment process with explicit hazard taxonomy, control hierarchy, and verification cycle. The risk score that emerges from a properly conducted PRA is a leading indicator, available in near-real time and longitudinally across repeated audit cycles, with a defensible theoretical pathway [anchored by the Core Proposition advanced in Section 6] to the lagging indicators on which current Social disclosure depends. PRA-augmented Social reporting therefore has the potential to convert ESG Social metrics from backward-looking catalogues into forward-looking risk dashboards. Whether investor-grade disclosure frameworks (Global Reporting Initiative [GRI], Sustainability Accounting Standards Board [SASB], European Sustainability Reporting Standards [ESRS S1] under the Corporate Sustainability Reporting Directive [CSRD]) can absorb audited PRA scores is a foreseeable integration question; the framework advanced here provides the theoretical justification.

4. Towards an Integrated Theoretical Framework

The Core Thesis

Sections 2 and 3 have prepared the conceptual groundwork. The thesis is that an organisation conducting systematic, ISO 45003-aligned Psychosocial Risk Assessments and acting on its findings through structural workplace changes will simultaneously reduce chronic workforce strain along the JD-R health-impairment pathway and reinforce engagement, autonomy, and retention along the JD-R motivational pathway. The behavioural and clinical signals carried along these two pathways include burnout scores from the health-impairment pathway, engagement levels from the motivational pathway, and voluntary turnover, absenteeism, and elevated health-care utilisation cutting across both. Mainstream ESG reporting frameworks can then absorb these signals as a leading, audit-grade input to the "Social" pillar of corporate ESG reporting, replacing lagging demographic counts with prospective risk indicators.

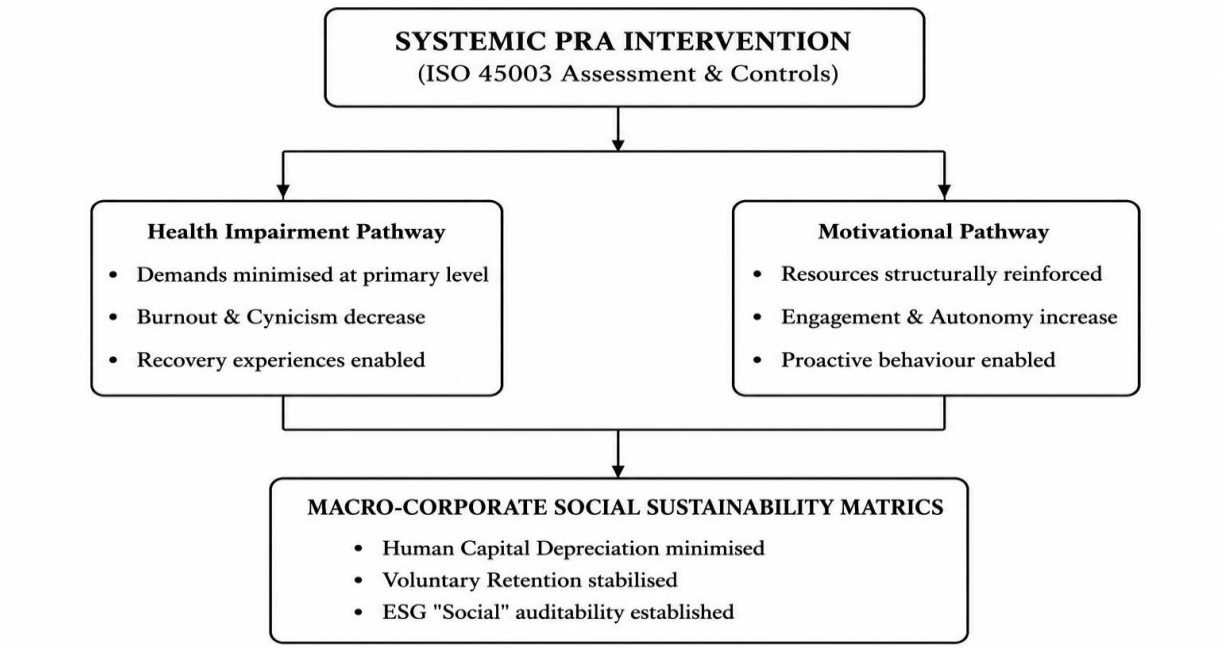
The thesis rests on three conceptual moves. First, ISO 45003's three domains supply the operational taxonomy: a structured vocabulary for the psychosocial hazards that the JD-R model otherwise treats abstractly. Second, the JD-R dual-pathway structure supplies the psychological mechanism by which hazard reduction produces distinct clinical and motivational outcomes in the workforce (Bakker et al., 2014; Bakker & Demerouti, 2016; Demerouti et al., 2001; Schaufeli & Bakker, 2004). Third, PRA outputs supply the corporate-accounting layer: auditable signals of the Social pillar's underlying quality that mainstream ESG disclosure frameworks are positioned to absorb.

The novelty of the framework lies in this explicit integration. The JD-R model, the ISO 45003 taxonomy, and the JD-R × ESG bridging logic have each been developed in their own literatures, but the three have not previously been combined into a single defensible theoretical architecture connecting micro-level hazard exposure with macro-level corporate human-capital accounting.

Conceptual Flow Diagram

The integrated logic is summarized visually below. A system-wide PRA acts upstream on both JD-R pathways; the pathways converge on macro-level corporate sustainability outcomes that current ESG Social reporting seeks, but is currently poorly equipped to capture.

Figure 1: The integrated framework: ISO 45003-aligned Psychosocial Risk Assessment as the upstream structural lever converging on macro-corporate social sustainability outcomes.



Reading Figure 1 from the top, ISO 45003-aligned PRA is positioned as the upstream structural lever (International Organization for Standardization, 2021). On the left, the health-impairment pathway is dampened: demands are minimized at the primary level, burnout and cynicism decrease, and recovery experiences become available to support depleted workers (Demerouti et al., 2001; Sonnentag & Fritz, 2007). On the right, the motivational pathway is reinforced: resources are provided structurally, engagement and autonomy rise, and proactive behavior is enabled (Bakker et al., 2014; Schaufeli & Bakker, 2004). Both pathways feed the bottom box — macro-corporate social sustainability metrics — where human capital depreciation is minimized, voluntary retention stabilizes, and ESG "Social" auditability is established.

Core Proposition

For readers new to this area, the framework can be condensed into a single Core Proposition that captures the central causal claim and provides an entry-point hypothesis for empirical investigation:

Core Proposition (P). *Organisations that implement systematic Psychosocial Risk Assessment anchored in ISO 45003 as a primary, structural intervention will exhibit measurable reductions in chronic workforce strain via the JD-R health-impairment pathway, simultaneous strengthening of engagement and retention via the motivational pathway, and consequently generate a leading, audit-grade input to the "Social" component of corporate sustainability reporting. Contemporary lagging demographic indicators cannot perform this leading, audit-grade input function.*

The Core Proposition integrates the theoretical claims developed across psychosocial safety climate (Dollard & Bakker, 2009; Dollard & McTernan, 2011), effort–reward imbalance (Siegrist, 1996, 2010), conservation of resources (Bon & Shire, 2022; Liao et al., 2021), and the recovery experiences tradition (Fritz et al., 2010; Kinnunen et al., 2011; Sonnentag & Fritz, 2007). Within the JD-R model, these four frameworks sit as compatible rather than competing lenses. A companion research-methods document contains the construct-level measurement guidance by which the Core Proposition can be operationalised, together with the sub-propositions interrogating each component strand empirically.

Contributions to Knowledge

The paper advances knowledge in four distinct ways. First, it provides the first explicit conceptual synthesis of the JD-R model and ISO 45003 in the published literature, bridging a compartmentalization that has

constrained both management and occupational-health psychology scholarship (Bautista-Bernal et al., 2021). Second, it reformulates PRA — conventionally understood as an HR compliance task — as a structured intervention variable capable of being positioned within causal models of corporate sustainability outcomes. Third, it advances the operationalization of ESG Social indicators by proposing PRA-augmented scoring as a leading metric superior to legacy lagging indicators. Fourth, it articulates PSC, ERI, COR, recovery experiences, and leadership behavior as compatible rather than competing lenses within a single framework, supplying theoretical humility about buffering conditions and specifying recovery experiences as a missing transfer mechanism.

5. Conclusion and Limitations

Limitations

Four structural limitations warrant explicit acknowledgement. First, the framework assumes that firms will adopt ISO 45003 in ways that produce substantive, evidence-informed risk profiles rather than box-ticking compliance artefacts. Although recent empirical work has demonstrated that deliberate implementation scaffolding achieves real-world adoption across diverse organizational contexts (Nebbs et al., 2025), the boundary conditions of that effect — particularly under conditions of regulatory capture, weak enforcement infrastructure, or thin internal audit capacity — remain uncharacterized. The Core Proposition's predictive validity will accordingly attenuate wherever PRA scoring diverges from the procedural integrity assumed here, and the framework should not be read as a guarantee of faithful adoption.

Second, the framework assumes cultural and labor-market contexts in which workers can plausibly act on the buffer resources that the JD-R model anticipates; its transportability into gig economies, informal-sector workplaces, and under-resourced healthcare systems — including those recently studied for sector-specific PSC dynamics (Mansour & Tremblay, 2019) — requires separate theoretical treatment.

Third, the framework does not specify the temporal lag structure between PRA intervention and downstream sustainability outcomes. This is, in part, a deliberate theoretical humility: the temporal profile is plausibly sector-dependent (longer in healthcare, shorter in knowledge work), and a single specified lag across sectors would misrepresent the underlying dynamics. The temporal choice is therefore left to empirical researchers rather than offered as a definitive theoretical prediction.

Fourth, reverse causality remains a methodological concern. It is empirically plausible that organizations experiencing high visible strain are *more* likely to initiate PRA — generating an observational correlation that runs in the opposite direction to the Core Proposition. Quasi-experimental designs alone cannot fully eliminate this confound; difference-in-differences, instrumental-variable approaches, and the natural-experiment opportunities created by staged national implementation of ISO 45003 (Nebbs et al., 2025) offer partial mitigation but do not constitute a definitive solution.

The buffering hypothesis itself is not universally supported empirically (Bakker et al., 2004); the resource-buffering strand of the framework should accordingly be interpreted as a magnitude claim whose detection requires structural rather than purely statistical specification. Cross-cultural instrument equivalence is also unresolved at the metric level (Section 3.6); comparative empirical work across collectivist–individualist and high–low power-distance contexts requires multi-group CFA before cross-jurisdictional inferences can be drawn (Bautista-Bernal et al., 2021; Dollard & McTernan, 2011).

Conclusion

The current corporate approach to employee burnout and social sustainability is fundamentally broken because it treats an organizational design flaw as an individual character flaw. By synthesizing the rigorous structural guidelines of ISO 45003 (International Organization for Standardization, 2021) with the validated dual-pathway psychological dynamics of the Job Demands–Resources model and by integrating that synthesis with PSC, ERI, COR, recovery experiences, the technostress tradition, and the ISO 45001 management-system architecture — this conceptual paper offers a corrective path forward. The Core Proposition advanced in Section 6 supplies an accessible entry-point hypothesis for newcomers to the area: systematic, ISO 45003-anchored Psychosocial Risk Assessment functions simultaneously as the structural lever that dampens

workforce strain, activates the motivational pathway, and produces an audit-grade leading input to the Social pillar of corporate sustainability reporting.

True human capital sustainability cannot be achieved through reactive, peripheral wellness strategies. It requires a fundamental shift toward primary prevention, treating psychosocial hazards with the same systematic, auditable accountability that has defined physical safety for over a century. Only when organizations treat the mental and emotional reserves of their workforce as a finite, protectable asset will corporate social sustainability transition from a marketing metric into an operational reality.

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Assessing Learner Readiness and Expectations for Metaverse-Based Education: A Pre-Survey Analysis of EON XR in Healthcare Service Quality Course

*Mohd Zulkifli Abdullah[1], Siti Noorsuriani Maon[1], Zaliza Azan[2], Elsa Roselina[3], Intan Akirah Zakri[4]
[1]Faculty of Business & Management, University Technology MARA (UiTM), Malaysia
[2]Faculty of Business and Accountancy, Universiti Poly-Tech Malaysia, Malaysia
[3]Vocational Education Program, Universitas Indonesia, Pondok Cina, Beji, Depok City, West Java, Indonesia
[4]Sunway Medical Centre Penang, Lebuh Tenggiri 2 Pusat Bandar Seberang Jaya, Perai, Pulau Pinang, Malaysia
Email: *m_zulkifli@uitm.edu.my, sitinoor123@uitm.edu.my, zaliza@uptm.edu.my, elsa@vokasi.ui.ac.id, intanakira15@yahoo.com
Corresponding Author: Dr Mohd Zulkifli Abdullah

Abstract: Immersive technologies, specifically augmented reality, virtual reality and Metaverse-based learning platforms have evolved higher education and have transformed the way higher education systems are taught and implemented. In healthcare education, these technologies could enhance students' comprehension of complicated knowledge by using realistic simulation strategies and three-dimensional visualization. This study was conducted to evaluate the technology readiness, students' prior experience and learning expectations regarding the deployment of the EON XR Metaverse platform in a healthcare service quality course. With a structured questionnaire, a quantitative cross-sectional pre-survey was conducted among 77 undergraduate students. It assessed digital readiness, availability of technology resources, exposure to immersive technologies and expectations about Metaverse-assisted learning. A descriptive statistical analysis indicates a high level that students have confidence and comfort in using digital technologies, which is a sign of very strong technological readiness. Moreover, participants were not familiar with AR/VR applications or the EON XR platform, indicating that immersive education was another area of study for most participants. Despite this lack of exposure, students expressed very favorable expectations towards Metaverse-based learning. They felt that EON XR would represent a more stimulating academic learning experience than traditional lectures, enhance visualization of healthcare service quality concepts and lead to better understanding. Overall, the findings revealed that students were willing and ready to work with Metaverse-enhanced education. Nonetheless, ensuring effective implementation will depend on proper orientation and technical assistance along with addressing differences in device accessibility and internet connectivity, to enhance both the learning process and equity in learning opportunities.

Keywords: *Metaverse, EON XR, Healthcare Service Quality, Digital Readiness, Student Expectations*

1. Introduction and Background

Education, however, has shifted drastically from the traditional, lecture-based model for academic education to immersive, technology-based educational frameworks. The "Metaverse," with special reference to its impact on the deployment of education in the education system, is a notion heavily developed after the COVID-19 pandemic, a worldwide disruption that led to a new way of teaching and learning that requires us to critically rethink, and then revolutionise, teaching and learning strategies globally (Lewis et al., 2024). This new digital horizon appears to be a 3D digital realm that leverages Virtual Reality (VR), Augmented Reality (AR), the internet and internet-related developments to form immersive, networked online experiences via the development of high-tech computing solutions (Popov et al., 2024; Chen, 2026). The Metaverse is the subject of high national ambition in countries like Malaysia, where education policies expect many user-friendly sites to be widely used in institutions. In this rapidly evolving and advanced ecosystem, platforms such as EON XR are adopting augmented and virtual reality to create experiential, hands-on learning environments connecting the physical and virtual worlds (Nguyen & Kim, 2024). For complex and applied fields namely, Healthcare Service Quality, spatial visualization and immersive scenario-based learning is a useful tool for bridging the gap between theory and practice (Bansal et al., 2022). Training in healthcare service quality is dependent upon students' understanding of complex organisational systems, patient-practitioner relationships and standardized clinical methods.

Simulation has become the backbone of healthcare education and training for generations as a potent and resource-demanding tool that reshapes medical education (Popov et al., 2024). Virtual reality and Metaverse

technologies provide them with immersive learning environments where students can conduct ultra-realistic simulations of care settings without having to jeopardize patient safety or the prohibitive capital spending required for the physical space (Lewis et al., 2024). The real ability to adopt such sophisticated tools is dependent heavily on end-user technological readiness and their infrastructure levels, and needs. However, there is a known readiness gap despite the potential benefits that increasing student engagement and cross-border collaboration could offer; this has largely depended on the relatively limited prior experiential exposure to immersive AR and VR technologies by students (Puiu & Udrițioiu, 2024). To fully integrate EON XR and other vast platforms into a healthcare service quality curriculum, we need to have a thorough understanding of the student's behavioural intent and technological self-efficacy. Model and assess factors such as user comfort, platform ease of use, compatibility with devices and interest of the learners to ensure a smooth user transition (Puiu & Udrițioiu, 2024).

The Healthcare Service Quality (HSM606) course is a key unit for the Semester 5 students attending the Bachelor of Health Administration course at Universiti Teknologi MARA (UiTM) Malaysia. The course is taught using an online course system on the internet through Google Meet, and in Semester 5, students are studying according to a flexible learning mode. The above-mentioned factors make online learning more flexible and accessible for both lecturers and students. The presence of online teaching environments has been criticised for providing low student participation and interaction, low engagement, and difficulty in sustaining their attention in the virtual learning environment (Martin & Bolliger, 2018; Bond et al., 2020; Dhawan, 2020). A particularly challenging aspect has to do with the course itself, i.e., the Healthcare Service Quality course. The syllabus provides access to extensive theory/health care quality frameworks, accreditation systems, patient-safety principles, and continuous quality improvement models requiring a significant amount of read/analysis and critical thinking. As a result, the student demographic often sees the subject as theoretical or a "dry course" where they receive little motivation to learn and often lack the ability to tie abstract theory to actual healthcare practice (Biggs et al, 2011; Means et al., 2014). Traditional courses for online learners may be thus inadequate for deep learning and learning to be learned in a meaningful way. To alleviate these challenges, the implementation of the EON XR Metaverse platform is an innovative strategy to integrate EON into teaching that integrates new teaching concepts based on experiential and constructivist learning theory. Emerging technologies, which provide rich and immersive educational experiences, allow students to see healthcare environments, interact in three-dimensional healthcare facilities, simulate real conditions in the healthcare environment and simulate quality management situations, that traditional online classes may be unable to present (Radianti et al., 2020), including Extended Reality (XR), Virtual Reality (VR), and Metaverse environments. These immersive educational experiences are conducive to active learning, collaboration and interactive experiences that result in enhanced student engagement in learning, which, in turn, contribute to enhanced students' comprehension, motivation and engagement (Makransky & Petersen, 2021).

Furthermore, the implementation of EON XR has the potential to connect theoretical learning with real-life encounters as students can encounter authentic healthcare service quality scenarios in a secure virtual environment. Given the burgeoning digitization of higher education, the use of the Metaverse for learning has the potential to improve teaching effectiveness and learning outcomes across higher education, especially in challenging classes, such as Healthcare Service Quality (Dwivedi et al., 2022; Tlili et al., 2022). Thus, the purpose of this study is to evaluate the technological readiness, experience and expectations of students when integrating the EON XR Metaverse platform into their coursework. Adopting a cross-sectional, pre-survey design covering three different academic cohorts, this study provides a comprehensive investigation into digital comfort and device accessibility, internet stability, and learning needs. The results will yield invaluable, data-driven insights on user behaviour to inform targeted teaching strategies to guarantee that the shift to Metaverse-based learning is equitable and meaningful.

2. Literature Review

The Evolution of Immersive Technologies in Higher Education

The Metaverse has radically transformed higher education into new learning environments that provide immersive, interactive, and dynamic classrooms as opposed to the usual classroom-based education context (Popov et al., 2024). This nascent digital realm encompasses VR, AR, and other immersive technologies to support virtual campuses, interactive simulations, and experiential learning scenarios (Lewis et al., 2024). The

Metaverse is, in a sense, the next generation of the Internet, where users experience a high degree of spatial presence embedded in a complex network of immersive virtual environments (Bansal et al., 2022). The growth of hardware and software to enable Metaverse development is speeding up, giving students access to a richer, more lifelike learning experience than with traditional virtual or augmented reality education.

The Metaverse concept has received a lot of buzz in the world of higher education in the past couple of years. It is a tool for the pooling of knowledge across disciplines through virtual learning environments where students from totally distinct academic backgrounds can collaborate, exchange ideas and collaborate on multidisciplinary projects (Lewis et al., 2024). The Metaverse brings students closer to actual practical situations in the real world, reducing physical restrictions, enabling an increased depth of learning through learning-by-doing approaches (Popov et al., 2024). Moreover, it presents unparalleled avenues for global collaboration as students and lecturers can interact across geographic boundaries, overcoming the geographical barriers of distance between campuses.

Virtual Reality and Simulation in Healthcare Education

Simulation is an efficient and resource-intensive technology that has revolutionized medical and healthcare education, transforming it altogether over the past decade (Popov et al., 2024). In medical education, it has been suggested that virtual reality (VR) is a new simulation technology that may deliver simulation in a more advanced manner that provides multiple advantages for medical educators and students by enabling affordable, standardized, repeatable, and on-demand technology in the medical arena (Bansal et al., 2022). VR is a computer-generated virtual world experienced through a variety of technical devices such as motion tracking, spatial audio, tactile hand controllers, and head-mounted displays (HMDs) that can produce 360-degree first-person views. These very modern products make the virtual environment incredibly immersive by providing a means for active participation, beyond the confines of traditional screens.

Past studies have repeatedly demonstrated the far-reaching potential of VR as a learning platform in medical and healthcare, explicitly discussing improved educational outcomes, increased speed of skills acquisition, greater retention, and the encouragement of hands-on learning (Lewis et al., 2024). VR has provided healthcare students the opportunity to experience realistic clinical and operational environments without placing patient safety in danger (Bansal et al., 2022). In a systematic review addressing teaching efficiency with a comparison between VR and traditional education, it was found that VR training led to a statistically significant improvement in students' clinical skills and practical performance (Popov et al., 2024). Research comparing HMD simulations with traditional teaching models (e.g., standard slides or linear videos) demonstrated that immersive VR dramatically accelerated the learning curve and heightened overall learner motivation.

The EON XR Platform: Capabilities and Pedagogical Impact

EON XR is a full-fledged platform that integrates exploration, creation, and guidance in fully immersive XR environments (Nguyen & Kim, 2024). A full-fledged Augmented and Virtual Reality application with features developed in-depth for remote learning and training in a high-level, hands-on and immersive environment. The program operates as a global, mobile-first ecosystem where academic skills are incorporated into real-world situations through immersive learning experiences and structured entrepreneurial routes. One of the key advantages of EON XR is its intuitive and completely code-free platform, which is designed to encourage both students and instructors to create content for deeper learning and engagement (Nguyen & Kim, 2024). By means of its intuitive and entirely code-free platform that fosters an intensively rich proprietary library of digital assets, users can rapidly make dynamic educational content in an instant on their mobile device, tablet, PC, or VR headset using a vast proprietary collection of digital content and resources.

Additionally, the platform is highly integrated with AI based on intelligent deep learning capabilities to improve the learning productivity of the educational processes. Its built-in spatial AI functionality is capable of auto-generating intricate lessons based on a user's course catalogue (enriched with vibrant images, targeted subtopics, rich media, and personalized quizzes). It also contains advanced AI avatars reflecting real-time personas for soft skills training, with intelligent feedback through complex simulations in context and real time. This level of interactivity is beyond what is possible today, as healthcare instructors can develop procedural training or assessment modules that automatically help train students through complex tasks in a relatively unscripted manner and contribute to the comprehension and acquisition of a skill and users can easily

complete and acquire new knowledge (Bansal et al., 2022).

Technology Readiness and the Technology Acceptance Model (TAM)

Even though Metaverse technologies promise powerful theoretical advantages, their integration and implementation largely depend on users' involvement, readiness, and positive behavioural intentions (Puiu & Udrițioiu, 2024). It is for educational institutions to give attention, first and foremost, to addressing the technical and social, psychological, and motivational dimensions of the Metaverse before it's even operational. New quantitative work based on the Technology Acceptance Model (TAM) has extensively examined university students' readiness to support metaverse platforms, discovering that prominent analytical constructs are technological self-efficacy, perceived usefulness, perceived ease of use, general attitudes, and behavioural intentions (Puiu & Udrițioiu, 2024). For example, some studies demonstrate that students often demonstrate high levels of above-neutral technological self-efficacy and claim to find metaverse tools to be very helpful, but their hands-on experience with AR/VR hardware is still significantly low. This disparity marks a critical readiness gap in higher education for the adoption of immersive technology.

Developing positive attitudes and high digital confidence is a crucial prerequisite for successful metaverse use in education, with attitudes and perceived behavioural control being identified as major predictors of student behavioural intention to use the technology (Puiu & Udrițioiu, 2024). Comfort, convenience, compatibility, interest, and effectiveness — researchers strongly emphasize the concept of breaking down readiness to use technology into these distinct variables. Comfort is a precise measure of the user's reaction to, and ease of use while using the Metaverse in education and learning. Convenience specifically measures how convenient using simulations within a live classroom lesson to enact and engage with. The compatibility aspect closely monitors how the students' and the lecturer's reactions change when adapting to the virtual environments of these new environments. These are the critical variables, that it is possible to measure prior to deployment, which may help educators customize their onboarding and manage the technology adjustment.

Challenges, Barriers and Infrastructural Considerations

The Metaverse adoption in academia is undoubtedly not without its significant limitations. The primary hurdles faced by institutions mostly consist of technical, social, and ethical elements, as well as pedagogical difficulties largely associated with the fit with ongoing curricula and continued content creation (Lewis et al., 2024). The challenge with broad adoption is that infrastructural restrictions consistently pose a significant hurdle to widespread adoption, so the first step before any implementation is to assess user access to powerful hardware devices and extremely stable internet connections. Initiating such data collection, many users report that meaningful access is often hard to obtain without friction to access on devices with older hardware, rendering the platform unreachable for a small segment of the population. In addition, the effectiveness of VR training is dependent solely on balancing technical usability against the cognitive demands on the user (Popov et al., 2024). Repeatedly, participants in various VR-based studies, have mentioned usability barriers surrounding poor accessibility, a high frequency of technological failures, limited variability of training situations, and so on.

Cognitive load in virtual reality (VR) space correlates highly with divided attention, painful physical experiences like sickness in simulator setup, and overall need for better guidance and platform knowledge (Popov et al., 2024). In some VR formats, the disconnect between this digital world and the real-world movement of the user can cause a deep sense of nausea. Thus, enhancing immersive VR training in healthcare is inherently related to increasing the design variability and establishing structured post-simulation debriefing sessions to optimize learning outcomes and also significantly minimize cognitive overload. Moving to a Metaverse implementation within teaching and learning in a university requires extensive time for adjustment, extreme patience, and careful onboarding. The transition from the offline classroom to the 3D realm is jarring for users being used to traditional face-to-face learning, and using standard two-dimensional online meeting applications. It is therefore very important to grasp the sensitive juncture of the student level for technology readiness and state-of-the-art capabilities of modern platforms such as EON XR, along with the demanding factors of good quality education in healthcare. This study successfully fills the gap in academic publications by offering firsthand data on learners' expectations and readiness before formal Metaverse integration that is directly empirical.

3. Research Methodology

Research Design

Such an empirical descriptive, cross-sectional quantitative study was used here. This method was selected because it is most efficient for understanding attitude, technological readiness, and expectation at a single point in time before an educational intervention. The quantitative pre-survey approach permits a structured collection of numerical data about a defined student body which is critical to identify a basic comprehension of technological self-efficacy and infrastructural access prior to the integration of complex immersive technologies (e.g., EON XR Metaverse platform). The cross-sectional nature of the design means that all data related to the participants' readiness to utilize Augmented Reality (AR) and Virtual Reality (VR) in the learning of Healthcare Service Quality was collected shortly before the start of the intended curriculum modules. This allows for the genuine, preconceived notions and prior experiences of the students to be isolated without intervention effects.

Participants and Sampling Strategy

The population for this study included students in undergraduate studies who were currently taking a Healthcare Service Quality module at university. Purposive sampling was used to pick the people who belonged solely to selected academic groups that studied the Metaverse-enhanced learning curriculum. The sample consisted of 77 people from three different classes for a Bachelor's degree in Health Administration, UiTM Puncak Alam. This sample size fit for exploratory baseline analytics and descriptive statistics analysis. The inclusion criteria required that participants be active undergraduate students without severe visual or cognitive impairments that would completely prevent the use of screen-based or immersive technology.

Research Instrument and Variables

Data were collected utilizing a structured, self-administered digital questionnaire titled "Pre-Survey: Knowledge on Application of Metaverse via EON XR in Learning for Healthcare Service Quality." The survey instrument was specifically designed to evaluate the practical and psychological readiness of the students. The questionnaire was divided into distinct sections mapping to the study's core variables, primarily measured on a standard 5-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree).

Section A: Demographic Information

This section contained the details of the respondents who participated in this study such as gender, student ID and name of class group.

Section B: Technological Readiness & Prior Experience

This core section consisted of five targeted items assessing the respondents' baseline digital competency and hardware capabilities:

General Digital Adoption: "I am comfortable adopting new digital technologies for educational purposes." (Evaluates general technological self-efficacy).

Immersive Technology Experience: "I have prior experience using Augmented Reality (AR) or Virtual Reality (VR) applications." (Establishes baseline familiarity with the medium).

Platform Familiarity: "I have previously used the EON XR platform or similar Metaverse learning environments." (Measures specific prior exposure to the intended educational software).

Device Accessibility: "I have access to a device (smartphone, tablet, or PC) capable of running AR/VR applications smoothly." (Assesses physical infrastructural readiness).

Internet Stability: "My current internet connection in Malaysia (campus or home) is stable enough for downloading and running 3D models/virtual environments." (Assesses network infrastructural readiness, a critical component for cloud-based spatial computing).

Section C: Expectations

This section featured two items designed to capture the students' perceived usefulness and pedagogical expectations of the Metaverse integration:

Anticipated Engagement: "I expect that learning through the Metaverse (EON XR) will be more engaging than traditional lectures."

Pedagogical Efficacy (Visualization): "I believe immersive AR/VR scenarios will help me better visualize and

understand healthcare service quality concepts."

Data Collection Procedure

Data were gathered among registered students of the Healthcare Service Quality course at Universiti Teknologi MARA (UiTM), Malaysia. Data were collected over the first week of the lectures so that an accurate baseline of student readiness was established before any formal exposure to the Metaverse curriculum. The questionnaire was distributed online (Google Forms) to allow prompt accessibility and capture of the data. The survey link was distributed to the students through their official academic communication channels (Ufuture and WhatsApp).

The pre-survey participation was entirely voluntary, and students were properly briefed about the purpose of the data collection procedures. It was also noted that responses would be used to customize the onboarding of the technology and not positively or negatively influence their academic grades. Responses were automatically timestamped and securely logged into an encrypted spreadsheet (Pre-Survey_ Knowledge on Application of Metaverse via EON XR in Learning for Healthcare Service Quality (Responses).xlsxpre survey.xlsx) to maintain data integrity and respondent confidentiality.

Data Analysis

After the survey window was closed, the raw data was extracted and evaluated in Python with the explicit use of the pandas library for effective data manipulation and statistical computation. The cleaning procedure verified completion of responses, anomaly detection, and reorganization of column headers for programmatic computation. All 77 surveys contained no incomplete surveys or missing data points (NAs) in the core Likert-scale variables.

Descriptive statistics were used as the main statistical methodology. The analysis computed:

Frequencies and Percentages: To show the demographic spread among the three academic groups.
Measures of Central Tendency (Mean): To analyse the mean agreement of the student body for every variable of technological readiness and expectation.
Measures of Dispersion (Standard deviation): To measure the spread of the responses (volatility) because this is essential to diagnose possible distributional inequalities in the infrastructure (e.g., wide range of devices or unstable internet).

The outcome of these descriptive measures supplied a rich, quantitative baseline for the latter discussion and pedagogy recommendations pertaining to the implementation and delivery of the EON XR platform.

4. Results

Overview of the Respondents

A total of 77 valid responses were obtained from undergraduate students who completed the pre-survey before participating in the EON XR Metaverse learning activities. Regarding the gender of the respondents, the majority of them, 91% (70 students) were female while only 9% (7 students) were male. The results also indicated that 35.1% (27 students) of the respondents were recorded from Group BA2654A while 29.9% (23 students) were from BA2654B, and 35.1% (27 students) of them were from BA2654C.

Reliability Analysis

Table 1: Reliability Analysis of the Study Constructs (N = 77)

Construct	Number of Items	Cronbach's α	Reliability Interpretation
Technological Readiness & Prior Experience	5	0.86	Good
Expectations	2	0.92	Excellent

Note. Reliability interpretation follows commonly accepted thresholds: α ≥ .90 = Excellent; .80–.89 = Good; .70–.79 = Acceptable (Hair et al., 2022; Taber, 2018).

This questionnaire's internal consistency was assessed using Cronbach's alpha (α) to test the reliability of measurement scales. Based on Table 1, the Technological Readiness and Prior Experience construct, consisting of five items, achieved a Cronbach's alpha coefficient of 0.86, indicating good internal consistency. This indicates that the items consistently reflect students' readiness to accept digital environments and their prior experiences with immersive technologies like AR, VR, and EON XR. The Expectations construct, having two items, exhibited a Cronbach's alpha of 0.92, meaning that the internal consistency was strong. The two items measuring whether students expected Metaverse-based learning to be effective or engaging exhibited a high reliability coefficient. The outcome indicates consistency in respondents' answers for the expectation items, confirming that the construct accurately reflects students' thoughts about learning through EON XR.

Overall, both constructs were above the cut-off threshold of 0.70, denoting acceptable reliability for use in practice (Hair et al., 2022). Findings also confirm that the measurement instrument has good internal consistency and is fit for follow-up statistical analyses such as descriptive statistics, correlation analysis, and regression analysis. In addition, the excellent reliability found for the Expectations construct enhances confidence in the robustness of the responses' reliability, whereas good reliability for the Technological Readiness and Prior Experience construct suggests that the items appropriately reflect a single construct. Thus, the questionnaire is seen as a relevant tool to assess undergraduate students' readiness and expectations for implementing the Metaverse (EON XR) technology into healthcare service quality education.

Descriptive Analysis

Table 2: Descriptive Statistics (N = 77)

Item	Mean	SD	Interpretation
Comfortable adopting new digital technologies for education.	4.35	.739	Very High
Prior experience using AR/VR applications	1.92	.791	Low
Previously used EON XR or similar Metaverse platforms	2.01	.716	Low
Have access to a suitable smartphone/tablet/PC	3.51	1.143	Moderate-High
Internet connection is stable enough for AR/VR learning	3.58	1.030	Moderate-High
Expect Metaverse learning to be more engaging than lectures	3.81	.828	High
Believe AR/VR will improve understanding of healthcare service quality	3.97	.827	High

There were a few important patterns that emerged from descriptive statistics. First, students were found to be extremely digitally ready (M = 4.35), showing that they were relatively well equipped with the ability to embrace new educational technologies. But exposure to immersive technologies was pretty minor in the past. The students had little prior experience with AR/VR applications (M = 1.92) and similar low familiarity with the EON XR platform (M = 2.01). By contrast, respondents reported moderate to high access to digital devices (M = 3.51) and acceptable internet connectivity (M = 3.58), indicating that the majority of students had the technological infrastructure in place for engaging in immersive learning exercises. More importantly, students had positive expectations regarding the educational potential of Metaverse learning. EON XR was expected to be more engaging than traditional lectures (M = 3.81) and participants believed immersive technologies would improve their understanding of healthcare service quality concepts (M = 3.97).

Summary of Mean and Standard Deviation

Table 3: Results of Construct-Level Descriptive Analysis (N = 77)

Construct	*M*	*SD*	Interpretation
Technological Readiness & Prior Experience	3.08	0.49	Moderate
Expectations	3.89	0.78	High

The descriptive statistics of the two study constructs, Technological Readiness and Prior Experience and Students' Expectations towards Metaverse (EON XR) learning, are summarised in Table 3. Overall, the results revealed that the students exhibited a modest degree of technological readiness and prior experience (M = 3.08, SD = 0.49), as the respondents were open to digital technologies in general whereas they had little prior experience with technologies such as Augmented Reality (AR), Virtual Reality (VR), and the EON XR platform, with immersive learning technologies. This result hints at the realization that the students have a decent level

of technological proficiency, but sometimes learning/orientation and training may be necessary before fully engaging with Metaverse learning.

On the other hand, students had high expectations of Metaverse learning implementation (M = 3.89, SD = 0.78). The greater mean score suggests that respondents predicted that the EON XR platform would lead to better engagement and better comprehension of ideas about healthcare service quality. Although they had only limited experience with immersive technologies, students also had a positive perception in terms of the educational opportunity of Metaverse-based learning and could be a useful teaching method. This indicates a strong intention to implement innovative instructional practices and demonstrates optimism among students toward the adoption of immersive technologies within higher education. Because the standard deviations for both constructs were relatively low (SD = 0.49 and SD = 0.78), it shows that the respondents' perceptions were somewhat consistent throughout the sample. Overall, these results reveal that although students may need additional exposure to immersive technologies, as a result of their positive expectations and positive attitudes toward digital innovation, students are appropriately positioned for Metaverse-based learning. These findings support preliminary evidence to establish EON XR as a novel teaching tool for education of healthcare service quality.

Detailed Analysis for Each Construct

Table 4: Detailed Analysis of the Study Constructs (N = 77)

Item	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Comfortable adopting new digital technologies for education.		1 (1.3%)	9 (11.7%)	29 (37.7%)	38 (49.4%)
Prior experience using AR/VR applications.	27 (35.1%)	29 (37.7%)	21 (27.3%)		
Previously used EON XR or similar Metaverse platforms.	19 (24.7%)	38 (49.4%)	20 (26%)		
Have access to a suitable smartphone/tablet/PC.	5 (6.5%)	9 (11.7%)	21 (27.3%)	26 (33.8%)	16 (20.8%)
Internet connection is stable enough for AR/VR learning.	1 (1.3%)	11 (14.3%)	24 (31.2%)	24 (31.2%)	17 (22.1%)
Expect Metaverse learning to be more engaging than lectures.		2 (2.6%)	29 (37.7%)	28 (36.4%)	18 (23.4%)
Believe AR/VR will improve understanding of healthcare service quality.		2 (2.6%)	21 (27.3%)	31 (40.3%)	23 (29.9%)

Students' Technological Readiness

Table 4 shows the willingness of respondents to use digital technologies before they adopted the EON XR Metaverse platform. Almost half of respondents (49.4%) strongly agreed, and 37.7% agreed they were comfortable with new digital technologies used for educational purposes. Only one respondent (1.3%) disagreed, showing overall very high digital confidence among participants. These results imply that most undergraduate healthcare students already have enough digital literacy to accommodate the use of immersive educational technologies. Digital readiness is seen as one of the greatest forces affecting technology acceptance and successful digital transformation in higher education (Dwivedi et al., 2022). In turn, students with digital tools tend to be more comfortable using technology and experimenting with new technology, in particular VR, and the Metaverse. These results are also consistent with the Technology Acceptance Model (TAM), which suggests users who have a higher technology self-efficacy will see the new technologies and tools they adopt as useful and easier to use and therefore act accordingly (Davis, 1989; Venkatesh et al., 2022).

Previous Experience with AR/VR Technologies

Despite high levels of digital confidence, students were inexperienced in immersive technologies. About 72.8%

disagreed or strongly disagreed that they had previous experience with AR or VR applications, and only 27.3% had a neutral answer. None of the respondents indicated prior agreement with it. For the same reason, previous exposure to EON XR and similar Metaverse learning environments was extremely limited. Almost three-quarters (74.1%) disagreed or strongly disagreed about their use of EON XR, whereas only 26.0% picked a neutral reaction. These results show that the respondents are first-time users of immersive educational technologies. Such a trait bolsters the study as students' perceptions after the implementation are less influenced by their previous experience or familiarity.

Recent research consistently identifies a lack of practical experience for students in the educational Metaverse, despite increased institutional interest in adopting Metaverse technologies, particularly in developing countries and healthcare education (Radianti et al., 2020). This means that the lack of prior exposure provides a significant opportunity for universities to gradually embed immersive technology into curricula over time, while providing sufficient orientation and technical support.

Accessibility of Learning Infrastructure

Overall, the respondents are perceived to have adequate access to technological infrastructure. Over half (54.6%) generally agreed and strongly agreed with the claim that they had devices that could run AR/VR programs, while only 18.2% disagreed. Roughly a quarter (27.3%) remained neutral. Likewise, 53.3% of respondents said that their internet connection was stable enough to download and use Virtual Learning environments. But around one-third of respondents, 31.2%, were neutral in this regard, and 15.6% said they lacked good internet coverage.

These results indicate that the technology infrastructure is generally a decent enough base for supporting Metaverse learning implementation, but the internet stability level continues to be a risk for a few users. Stable internet connectivity has been consistently found to be one of the main factors contributing to the effectiveness of immersive learning as rendering three-dimensional environments demands a higher bandwidth than traditional online learning platforms (Evans et al., 2023). As such, educational institutions that utilize Metaverse-based teaching should explore aspects such as hybrid learning approaches, optimized media-rich education, and technical support to reduce interruptions brought on by network impairments.

Students' Expectations toward Metaverse Learning

On the other hand, students expressed very positive expectations concerning the educational impact of EON XR. In terms of learning engagement, 59.8% either agreed or strongly agreed, (whereas 2.6% disagreed) that learning through the Metaverse would be more engaging than conventional lectures. On the other hand, 37.7% were neutral. In a similar vein, 70.2% agreed that they believe immersive AR/VR scenarios would enhance their comprehension of healthcare service quality concepts, and 2.6% disagreed. The overwhelmingly positive expectations indicate a strong degree of acceptance by the students long before the tech is introduced to them. According to expectancy-value theory, learners who expect benefits from the learning experience are motivated to participate actively in the learning experience. These results are consistent with recent evidence showing that the combination of immersive learning environments and the experiential learning of students, which enables students to visualize abstract healthcare processes in realistic virtual environments, increases learner engagement, enhance conceptual understanding (Kye et al., 2023; Tlili et al., 2022).

Discussion

The current study aimed to understand the readiness and expectations of undergraduate healthcare students at the beginning of the implementation of the EON XR Metaverse application within healthcare service quality education. Overall, students have relatively low exposure to immersive technologies but show significant digital readiness and positive beliefs about the educational value of Metaverse-based studies. These findings corroborate earlier research indicating that students are becoming more open to new educational technologies despite their lack of hands-on experience (Dwivedi et al., 2022; Tlili et al., 2022). An additional finding is the high level of confidence in the digital environment. Almost 90% of those surveyed reported being comfortable implementing new digital technologies for educational purposes. This finding highlights the traits of today's Generation Z learners who come from technology-rich contexts and tend to adopt digital innovations better than previous generations (Prensky, 2001; Dwivedi et al., 2022). Digital confidence has consistently been identified as a significant predictor of technology acceptance, as students with stronger digital self-efficacy find

new technologies more useful and intuitively easy to navigate and use (Venkatesh et al., 2022).

As per the Technology Acceptance Model (TAM), perceived ease of use and perceived usefulness play an important role in predicting users' behavioural intentions to adopt educational technology (Davis, 1989). However, respondents reported virtually no prior experience with EON XR and low exposure to AR/VR technologies despite reporting high levels of digital confidence. Over 70% had not used AR/VR applications; close to three-quarters were novices to EON XR or similar Metaverse learning environments. This finding agrees with recent systematic reviews revealing that even though research into immersive learning is very much growing, the actual implementation in higher education has been quite restricted, especially in developing countries and healthcare education (Radianti et al., 2020). Similar results were reported by Tlili et al. (2022), who concluded that the educational Metaverse is still in its early adoption stage globally. The sparse experience seen in students offers opportunities for educators because post-implementation learners' perceptions are less likely to be influenced by familiarity and technological bias beforehand. Instead, learners will be evaluated primarily by their own authentic experiences of learning the platform.

Prior studies indicate that this first experience with immersive learning environments usually produces considerable levels of curiosity and motivation with educational design and technical support being sufficient (Kye et al., 2023). The results also suggest that subjects have a good level of tech infrastructure to support in-depth learning. Over half of the study participants claimed they had the appropriate devices to run AR/VR applications and a similar proportion said they had stable internet to be able to use virtual learning environments. However, around a third of them were unsure of the quality of the internet. This finding aligns with prior literature which reports the use of tech infrastructure and internet stability as significant obstacles to meaningful Metaverse implementation (Evans et al., 2023; Dwivedi et al., 2022). Higher education institutions can have accessible technical, online, and device support to integrate immersive learning. A surprising and perhaps the most positive finding may arise from the expectation of students about the educational benefits of EON XR. Over 60% thought learning through the Metaverse would be more interesting than a typical lecture, and more than 70% thought immersive AR/VR experiences would be useful to help them comprehend concepts of service quality in healthcare. This aligns with the constructivist framework for learning that the idea that learning is achieved when learners actively construct knowledge, rather than by passively receiving information (Popov et al., 2024).

Immersive technologies allow students an opportunity to learn through experiencing real-world virtual healthcare environments, engaging in simulated interactions, and visualizing abstract concepts that are difficult to explain using traditional methods of teaching (Kye et al., 2023). Healthcare service quality is integrally interconnected involving: communication, delivery of care, individual patient engagement, quality improvement, organisational processes and the delivery of the service. Such more complex interactions might not be well captured in traditional classrooms. The Metaverse offers experiential simulations, within which students learn about patient journeys, examine healthcare processes and practise decision-making in a realistic, virtualized environment - without compromising patient safety (Radianti et al., 2020). Such immersive experiences can enhance conceptual understanding, knowledge retention, learner engagement, and critical thinking skills (Tlili et al., 2022). At least from the perspective of the Technology Acceptance Model (TAM) students pre-conceptualize the value of Metaverse learning. Perceived usefulness is considered one of the best predictors of behavioural intention to adopt new educational technology in education (Davis, 1989; Venkatesh et al., 2022). As a result, these positive expectations contribute greatly to establishing EON XR in the implementation of EON XR in healthcare teaching.

The results of the current study also have implications with regard to the practical side for curriculum development. Universities that will undertake immersive learning must realise that digital literacy does not mean competence in immersive learning. Orientation, technical training, scaffolded learning activities, structured interventions and an ongoing stream of technical support all remain key to enhancing maximum learning experiences for students (Dwivedi et al., 2022; Tlili et al., 2022). Also, there should be continuous professional development in the form of faculty preparation for lecturers on how to develop effective pedagogical strategies for integrating immersive technologies with the traditional way of teaching to effectively use the technologies. Thus, the investigation shows promising baseline conditions for the implementation of EON XR in undergraduate healthcare education. Students have a high level of digital readiness, are sufficiently

equipped with technological infrastructure and hold positive expectations even when they have little experience with immersive technologies. Overall, these results provide an auspicious basis for future investigations to examine the learning effectiveness of Metaverse technology on students' knowledge acquisition, student engagement, critical thinking or healthcare service quality capability after actual implementation in reality (Kye et al., 2023; Radianti et al., 2020).

5. Implications and Conclusion

Educational Implications

This results in many implications for healthcare management education. Firstly, universities should not assume that students possess prior experience with immersive technologies simply because they are digitally competent. Thus, onboarding should be done in structured orientation sessions before immersive learning activities are performed. Second, curriculum developers must realize that students demonstrate strong enthusiasm toward innovative learning methods. This favourable stance is a crucial point from which to incorporate Metaverse technologies into education in high-quality healthcare service settings. Third, institutions will need to continue investing in their digital infrastructure and training their lecturers. The effectiveness of such a concept is contingent on more than simply the availability of technology; educators require the ability to design meaningful immersive learning experiences that reflect course learning outcomes.

Conclusion

This study provides important baseline evidence regarding undergraduate students' technological readiness and expectations toward the integration of the EON XR Metaverse platform in Healthcare Service Quality education. The findings indicate that students demonstrated a high level of digital confidence, with strong comfort in adopting new digital technologies for educational purposes. However, this readiness was not accompanied by substantial prior exposure to AR/VR or EON XR, highlighting a clear distinction between general digital competence and immersive technology experience. This finding is consistent with recent research suggesting that although immersive technologies are receiving increasing attention in higher education, their practical adoption remains at an early stage, particularly in healthcare education (Radianti et al., 2020; Tlili et al., 2022). Despite limited prior experience, students expressed high expectations toward Metaverse-based learning, particularly in relation to engagement and the visualization of complex healthcare service quality concepts. The findings therefore support the potential of immersive technologies to facilitate experiential and constructivist learning by enabling students to interact with realistic virtual environments and connect theoretical concepts with practical situations (Kye et al., 2023; Tlili et al., 2022). From the perspective of the Technology Acceptance Model, students' positive perceptions of the potential usefulness and accessibility of the technology may provide a favourable foundation for subsequent adoption (Davis, 1989; Puiu & Udrițioiu, 2024).

Nevertheless, successful implementation should not be assumed solely from students' digital confidence. The moderate levels of device accessibility and internet stability indicate that infrastructural inequalities may influence students' ability to participate effectively. Therefore, structured orientation, technical support, appropriate infrastructure, and lecturer preparedness are essential to ensure an inclusive and meaningful immersive learning experience (Dwivedi et al., 2022; Popov et al., 2024). Overall, the study establishes a positive baseline for implementing EON XR in healthcare service quality education while highlighting the need for appropriate pedagogical and technical preparation. Future research should compare pre- and post-intervention outcomes to determine whether positive expectations translate into measurable improvements in learning effectiveness, engagement, confidence, and satisfaction. Such evidence would further clarify the educational value of Metaverse-based learning in healthcare management education.

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EcoBytes: Enhancing Teaching and Learning in Economics through Short-Form Microlearning Videos

J.S. Keshminder[1], Afiza Azura Mohamad Arshad[1], *Nur Azirah Zahida Mohamad Azhar[1,2]
[1]Faculty of Business and Management, Universiti Teknologi MARA, Puncak Alam, Selangor, Malaysia
[2]Institute of Business Excellence, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia
Email: keshm967@uitm.edu.my, afiza400@uitm.edu.my, *azirahazhar@uitm.edu.my
Corresponding Author: Dr Nur Azirah Zahida Mohamad Azhar

Abstract: The fast pace of the digital revolution in education and the changing learning habits of Generation Z learners have presented challenges to the traditional methods of teaching economics. Students accustomed to concise, visual and mobile content may be less receptive to lecture-based instruction when faced with abstract and conceptually demanding topics. This research examines EcoBytes, a microlearning platform that offers short videos on economics through TikTok and YouTube Shorts, connecting to additional learning resources such as QR-coded links to full lectures, quizzes, case studies on Universiti Teknologi MARA's UFuture learning management system, PowerPoint summaries and printable worksheets. A quasi-experimental pre-test/post-test design was used in which undergraduate students completed structured assessments before and after use of EcoBytes. Descriptive statistics were employed to contrast item-level error percentages and overall score distributions. The results show a reduction in the number of errors in the selected items and an upward shift in the distribution of scores on the post-test. This indicates an improvement in conceptual performance as a consequence of the intervention. Student engagement was not directly measured and is discussed as a possible benefit. The study is based on the Cognitive Load Theory, Microlearning Theory, Constructivist Learning Theory and Technology Acceptance Model and presents EcoBytes as a flexible supplementary approach to support economics learning with short-form digital content.

Keywords: *Micro-learning, SDG 4, Academic Integrity, Blended Learning, Digital Pedagogy*

1. Introduction

The fast digitalization of education has revolutionized teaching and learning in higher education globally. The advent of digital technologies, web-based learning, and mobile applications has created new ways for the distribution, access, and interaction with knowledge, making learning environments more interactive and flexible (Kumar & Priyanka, 2023; Mateo-Guillen & Cortijo Ocaña, 2025). The rise in blended and virtual learning environments has supported the continuity of academic activities and increased access to learning resources, thus intensifying this shift (Khilji, 2022). There is thus an increasing trend toward digitally mediated learning models that emphasize flexibility, personalization and student-centred engagement alongside regular classroom-based teaching (Belanova & Popok, 2025; Mateo-Guillen & Cortijo Ocaña, 2025). These developments are especially important in disciplines which have complex theoretical concepts and therefore require pedagogical approaches that foster understanding and motivation.

But even with these advances the pedagogical problems of economics education are not solved. Traditional lecture-based approaches are still common, but they can generate passive learning environments where students depend heavily on instructors instead of actively engaging with course content (Adnan et al., 2025). Such approaches may also constrain opportunities to critically assess economic concepts and apply theoretical knowledge to real-world contexts. Economics classes are also frequently heavily dependent on textbooks and static teaching resources that might not be appropriate for the multimedia-rich learning environments that today's students are accustomed to. Previous research has demonstrated that abstract economic concepts cannot be easily understood by traditional teaching methods alone, highlighting the need for more interactive and engaging approaches (Wong et al., 2024; Fanni & Lakrarsi, 2026).

Another challenge in economics education is student motivation and engagement. Studies show that students perform moderately in economics-related courses and show low motivation in their studies (Adnan et al., 2025). One reason could be that students perceive the subject as hard, and they may not have many opportunities to learn interactively. In response, mobile gamification, simulated environments and game-based learning have been proposed as a means of promoting more active learning. Simulation games and metaverse environments can provide immersive experiences that model real economic conditions and can foster learning

outcomes and student interest (Wong et al., 2024). Such developments show the potential of digital technologies to make economics education more interactive and experience-based.

At the same time, the wider digitalization of higher education has brought opportunities and challenges. Artificial intelligence (AI), virtual reality (VR), and adaptive learning systems are used more and more in support of personalized learning (Fanni & Lakrarsi, 2026; Bautista, 2026). These technologies can allow for active learning and more customized instructional pathways. However, their use also raises questions of access, infrastructure preparedness, staff capability and ethical use of AI-powered tools in academic settings (Bautista, 2026; Pretorius, 2025). An over-reliance on automated systems may also undermine independent learning if students uncritically engage with such tools. Educators then need to balance technological innovation with learning experiences that continue to promote conceptual understanding and critical thinking.

The digital transformation has also altered the roles of teachers and students in the learning ecosystem. The use of digital learning tools is becoming more widespread, and so educators are becoming facilitators who guide students through interactive and technology-supported learning environments instead of transmitters of knowledge (Belanova & Popok, 2025). At the same time, students are taking greater ownership of their learning through digital resources, collaborative tools and independent learning activities. Consequently, more importance has been attached to self-guided learning, online literacy, and the intentional use of technologies to foster participation in the learning process (Kumar & Priyanka, 2023; Tapia et al., 2023).

The learning environment has changed with the increased use of social media and mobile platforms for education. Besides communication, social media platforms are also used for knowledge sharing, professional networking, and informal learning in higher education (Al-Hail et al., 2024). They enable students to find information and interact with learning content quickly on digital platforms they are familiar with. The widespread use of smartphones by university students has also increased the opportunities for mobile learning, through which students can get access to educational materials across locations and at different times.

But the use of social media in teaching and learning is still limited in a formal way. Social media platforms are used extensively for communication and sharing knowledge, but there is still a lack of structured pedagogical frameworks for integrating them into formal learning and assessment (Al-Hail et al., 2024). The literature has also explored digital innovations such as gamification, virtual learning environments, and immersive technologies, but the systematic use of short-form social media video as a structured learning tool in academic disciplines such as economics has been relatively less studied.

This gap has particular relevance for Generation Z learners, who have grown up in digitally connected environments and are familiar with mobile devices, social media and instant access to information. Research shows that such learners have a preference for visual, interactive, and concise learning materials available on demand (Ninčević & Jurić Vukelić, 2025; Priyanshu et al., 2025). Thus, short-form video formats on platforms like TikTok and YouTube Shorts provide a potentially useful vehicle for the delivery of condensed educational content in ways that fit with current digital learning behaviors.

These changing learning dynamics within economics education led to the development of EcoBytes as a microlearning ecosystem. Short videos on TikTok and YouTube Shorts are used to describe economic concepts in brief, digestible segments. Besides the short-form content, more extensive learning resources are available such as QR-coded links to full lectures, quizzes and case studies via Universiti Teknologi MARA's UFuture learning management system, PowerPoint summaries and printable worksheets. These materials are designed for mobile access, so students can review content in a flexible manner, and the short videos can serve as entry points into more detailed learning activities.

Although microlearning and social media are used more and more in informal learning, research on the systematic use of TikTok and YouTube Shorts in economics education is limited. Thus, this research studies the implementation of EcoBytes as a systematic microlearning ecosystem and investigates the effects on students' performance with a quasi-experimental pre-test/post-test design. The study examines whether the item-level error rates and distributions of total scores improve after students use the EcoBytes intervention.

2. Literature Review

Economics Education Challenges

For many years, economics education has been associated with issues of student engagement, conceptual understanding and effective pedagogy. Many economic theories and models are abstract and demand that learners understand relations among several variables. Therefore, students may face significant cognitive loads when learning concepts such as market equilibrium, elasticity, and macroeconomic fluctuations, particularly when these are primarily taught using lecture-based methods (Adnan et al., 2025). This can make it difficult for some students to retain these ideas, or to apply economic reasoning to real-world situations.

Concept overload can also arise from the complexity of economic theory, where students may have to process several abstract concepts simultaneously, leading to concept overload. Dense textual materials and long lectures may make it difficult for learners to integrate new information with their existing knowledge. Research into higher education has criticized approaches to pedagogy that are too passive and give students few opportunities to take an active role in the learning process (Adnan et al., 2025; Kendaganna Swamy et al., 2026) as a consequence.

Passive learning remains a concern in economics classrooms, especially in large lecture-based courses where interaction between instructors and students may be limited. In such contexts, students may become reliant on explanations provided by the instructor and may have fewer opportunities to develop their own interpretations of economic concepts. Research has suggested that students accustomed to interactive and technology-enhanced learning experiences might find traditional lecture formats less engaging (Adnan et al., 2025; Kendaganna Swamy et al., 2026). This can lead to the subject of economics being seen as abstract and a case of memorizing rather than understanding concepts.

Low motivation and low engagement are also frequently cited in economics education. Research has shown that students may only perform and be motivated to a certain degree due to the difficulty of the subject and the sporadic use of engaging instructional strategies (Adnan et al., 2025). In response to these concerns, educators have explored technology-supported approaches such as gamification. When designed with the right challenges, feedback and rewards, gamified learning can support motivation and self-directed learning (Adnan et al., 2025).

In general, the literature emphasizes the need for pedagogical strategies that make learning economics more interactive, more accessible, and more closely linked to application. As higher education responds to digital transformation and changing student expectations, educators are blending technology-enhanced learning tools, collaborative activities and real-world examples to overcome abstract theory, overload of concepts and student disengagement.

Microlearning in Higher Education

Microlearning is an emerging instructional approach that has the potential to address some of the limitations of traditional teaching in higher education. It's about packaging educational content in small, focused chunks that can be consumed in a relatively short period of time. Microlearning is not similar to long lectures or extensive reading materials. It is focused on specific concepts or skills and aims to facilitate the processing and revisiting of learning content (Susilana et al., 2022).

One theoretical framework for microlearning is Cognitive Load Theory. The theory states that learning is limited by the capacity of the working memory. Cognitive overload occurs when instructional materials contain too much information at once which may hinder comprehension and retention (Susilana et al., 2022). This is where microlearning comes in as it breaks complicated content into smaller units so that learners can focus on the key ideas with less extraneous cognitive load.

Empirical studies have reported positive results of microlearning in higher education. Studies on online learning have found that segmenting instruction into smaller chunks can reduce cognitive load and promote student performance (Susilana et al., 2022). In a similar vein, research on microlearning course design indicates better student engagement, satisfaction and academic performance when learning materials are organized into focused, manageable segments (Kossen & Ooi, 2021).

Microlearning also fits very well with mobile learning environments. Research has found that mobile microlearning, delivered via smartphones and other portable devices, has been linked to greater cognitive efficiency and reduced learner fatigue than more traditional forms of mobile learning (Yuca & Dabaj, 2025). Short, interactive modules can give students more flexibility in deciding when and how to interact with learning materials, which is especially important for learners who often use mobile devices to access information.

Another benefit of microlearning is that it encourages ongoing and self-directed learning. The individual modules usually focus on one concept or skill, allowing students to revisit particular topics when they need reinforcement. Microlearning can also be embedded in learning management systems, mobile apps and social media platforms, allowing it to be adapted to different learning contexts.

With the demand for flexible and accessible learning resources growing, microlearning is receiving more and more attention in higher education. Chunking content into smaller units could reduce unnecessary cognitive load and provide for active review and retention of knowledge. These traits make microlearning a relevant approach for subjects in which students need repeated exposure to complex ideas.

Social Media as Learning Platforms

Recently, social media platforms have been increasingly considered as additional tools for teaching and learning in higher education. Platforms like YouTube, TikTok, Instagram and WhatsApp were originally designed for communication and social interaction but now they are used for knowledge sharing, collaboration and informal learning (Sadrul Huda & Shupti, 2025). Educational material can be viewed by learners via multimedia features such as videos, discussions and interactive posts.

Particularly important for knowledge dissemination and informal learning are video-sharing sites. For example, YouTube allows educators and content creators to share instructional videos with large audiences worldwide. The research on the educational value of YouTube demonstrates that user-generated video content and interaction via comment features can enable knowledge exchange and collaborative learning (Dubovi & Tabak, 2019). These platforms also allow students to review the content at their own pace.

Social media can also help foster collaborative learning and peer interaction in educational environments. Studies on WhatsApp use in university courses indicate that the platform can improve communication, information sharing and collaborative problem-solving outside the classroom (Basitere et al., 2019). Similarly, peer-tutoring activities on social media demonstrate the ways the online environment can aid in the interaction between the students and the instructors (Campbell, 2019).

The explosive growth of short-form video platforms like TikTok, Instagram Reels and YouTube Shorts has expanded the educational potential of social media. These platforms enable users to share information concisely, in attractive visual forms that are accessible through mobile devices (Sadrul Huda & Shupti, 2025). So educators have started turning to short-form videos for tutorials, quick explanations and other bite-sized instructional content.

Nevertheless, the formal incorporation of social media into educational practice is uneven. Past studies have highlighted the need for pedagogical models that facilitate intentional social media use for teaching and learning (Campbell, 2019; Dubovi & Tabak, 2019). As social media becomes more entrenched in the everyday digital practices of students, the role of social media in formal academic learning remains an important area for future research.

Generation Z Learning Behavior

Understanding Generation Z's learning preferences is important to design modern higher education environments. Generation Z, usually defined as those born from the mid-1990s to the early 2010s, has grown up in a highly interconnected digital environment and has a great deal of experience with digital technologies, social media and mobile devices (Ninčević & Jurić Vukelić, 2025). Many learners' experiences affect the ways they access information and engage with educational content.

One of the often cited features of Gen Z learners is their preference for visual and interactive learning aids. Research indicates that these students are more receptive to multimedia tools like videos, infographics, and interactive applications, rather than solely text-based resources (Ninčević & Jurić Vukelić, 2025; Priyanshu et al., 2025). This preference is directly related to their knowledge of digital media and their use of mobile devices as a common source of information.

Generation Z learners are also often associated with a preference for short and focused learning content that can be accessed efficiently in digitally rich environments (Ninčević & Jurić Vukelić, 2025). This is not to say that complex learning should be oversimplified; rather, instructional content can be chunked into manageable pieces that allow for sustained attention and progressive understanding. Therefore, long lecture-only formats could be supplemented with shorter digital resources.

Digital learning tools and microlearning methods are well-suited to these preferences. Short videos and interactive micro-content can offer short learning units supporting engagement and knowledge acquisition (Priyanshu et al., 2025; van Wyk, 2022). Furthermore, mobile learning apps enable students to access learning materials across locations and at different times, thereby increasing the flexibility of study (Subbarao & Khan, 2024).

Research also shows that Generation Z learners may favour learning environments that incorporate technology with opportunities for interaction and collaboration. Online platforms can foster motivation and participation in academic activities through social learning, peer communication and timely feedback (Piatrov & Krajčovič, 2025). The relevance of smartphones is particularly high as they are often a key tool for accessing educational content and participating in online learning (Piatrov & Krajčovič, 2025).

Such features demonstrate the need for the design of learning environments that respond to current digital practices, but still have clear pedagogical goals. Conventional teaching can be merged with visual resources, mobile access, and interactive learning activities to produce more flexible and accessible learning experiences. EcoBytes brings together short educational videos and additional digital learning materials in this context. Focused economics content is delivered through TikTok and YouTube Shorts, with other materials allowing for more detailed study and application. Thus the platform is designed to supplement rather than supplant traditional economics teaching.

The potential of EcoBytes as a micro-learning ecosystem in teaching economics can be discussed with reference to a number of well-developed educational and technology adoption theories. Specifically, Cognitive Load Theory, Microlearning Theory, Constructivist Learning Theory and the Technology Acceptance Model (TAM) provide useful theoretical insights into why short-form video learning environments, such as EcoBytes, are effective in enhancing student engagement and learning in higher education.

Cognitive Load Theory

According to the Cognitive Load Theory, the best learning happens when instructional resources are designed to fit the limited processing capacity of the human working memory. If the learners are given too much information at one time, it can lead to cognitive overload, which will hinder later understanding and retention of what was learned. In the traditional lecture-based approach, students are often bombarded with a lot of information in one session which can lead to cognitive overload and less learning efficacy.

This is where short-form learning such as EcoBytes, which distils information into smaller and manageable chunks, can help. Micro-learning techniques with small content help students to focus on one concept at a time which reduces the extraneous cognitive load and improves retention. Research on micro- and nano-learning indicates that short, intense learning modules based on cognitive science could be very successful for knowledge retention and just-in-time learning (Misra et al., 2026). EcoBytes provides short video clips that are easy for students to consume as they are presented in digestible bites, allowing students to better process information rather than be bombarded with theoretical material.

Theoretical Foundations of EcoBytes

Using a number of established educational and technology adoption theories, the potential contribution of EcoBytes to economics education can be examined. The Cognitive Load Theory, Microlearning Theory,

Constructivist Learning Theory, and the Technology Acceptance Model (TAM) offer complementary explanations of the potential of a short-form digital learning environment to support learning and promote the use of educational technologies in higher education.

Cognitive Load Theory

According to the Cognitive Load Theory, learning is improved in the case of instructional materials adapted to the limited processing load of working memory. Too much information presented to the learner at one time can cause cognitive overload, making it harder to remember and understand the information. In a traditional lecture setting a large amount of information may be provided in one session and the likelihood of cognitive overload increases.

Short-form learning is a solution to this problem where information is delivered in smaller digestible chunks. Microlearning lets students focus on one concept at a time, which can reduce extraneous cognitive load and support retention. Research on micro-learning and nano-learning suggests that short, focused units can assist in knowledge retention and just-in-time learning (Misra et al., 2026). This is the approach of EcoBytes, which offers economic concepts in brief video clips that can be studied independently or linked to the more comprehensive course content.

Microlearning Theory

The theory of microlearning is that learning content is delivered in small, targeted learning units that are easily accessible and digestible. Microlearning focuses on discrete concepts or skills rather than long lectures or large reading assignments, so learners can work through content in digestible chunks. This is consistent with the flexible learning practices of students who regularly use digital resources.

Research in higher education indicates that microlearning can support student engagement and learning outcomes by reducing extraneous cognitive loads and facilitating retrieval of content. Microlearning approaches can also allow learners to study across locations and times, increasing flexibility and allowing for greater autonomy (Skalka & Drlík, 2018). Microlearning pedagogy also highlights clear objectives, individualized learning paths, continuous feedback, and interactive digital resources (Alias, 2025).

EcoBytes follows these microlearning principles, curating economics content into short videos around specific themes. Each video has a short explanation with visual aids so students can review a key concept before moving on to more in-depth learning materials. This structure also allows learners to go back to topics when they need further reinforcement and thus promotes self-directed learning.

Constructivist Learning Theory

Constructivist Learning Theory views learners as active participants who construct understanding through interaction, collaboration, reflection, and experience, rather than passively receiving information from instructors. From this perspective, effective learning environments offer students opportunities to interact with content and relate it to prior knowledge and to construct meaning through active learning processes.

Microlearning environments may facilitate constructivist learning if they offer opportunities for interaction, practice and collaboration. Increased interaction and knowledge construction have been linked to participatory approaches in which learners are involved in developing or employing digital microlearning resources (Manrique-Losada et al., 2026). Similarly, digital microlearning systems combined with practice-based learning can assist learners to link theoretical concepts with applied skills (Su et al., 2026).

EcoBytes promotes constructivist principles by connecting short-form content with quizzes, worksheets, longer lecture materials and other learning activities. This combination allows students to move beyond passive watching of videos and to engage with economic ideas through a variety of formats and multiple learning pathways.

Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM) offers a framework to understand students' adoption and use of educational technologies. According to TAM, the use of technology is largely determined by perceived

usefulness and perceived ease of use. Technology use is more likely to be adopted by learners when they perceive the technology as being supportive of their learning and easy to use.

Research on digital and microlearning contexts has suggested that perceived usefulness can affect learners' intention to adopt educational technologies. When students see a microlearning platform as useful for flexible and autonomous learning, their motivation to use the platform could be increased (Zambrano Verdesoto & Caicedo, 2025). There may also be lower barriers to adoption due to familiarity with mobile interfaces and short-form video formats.

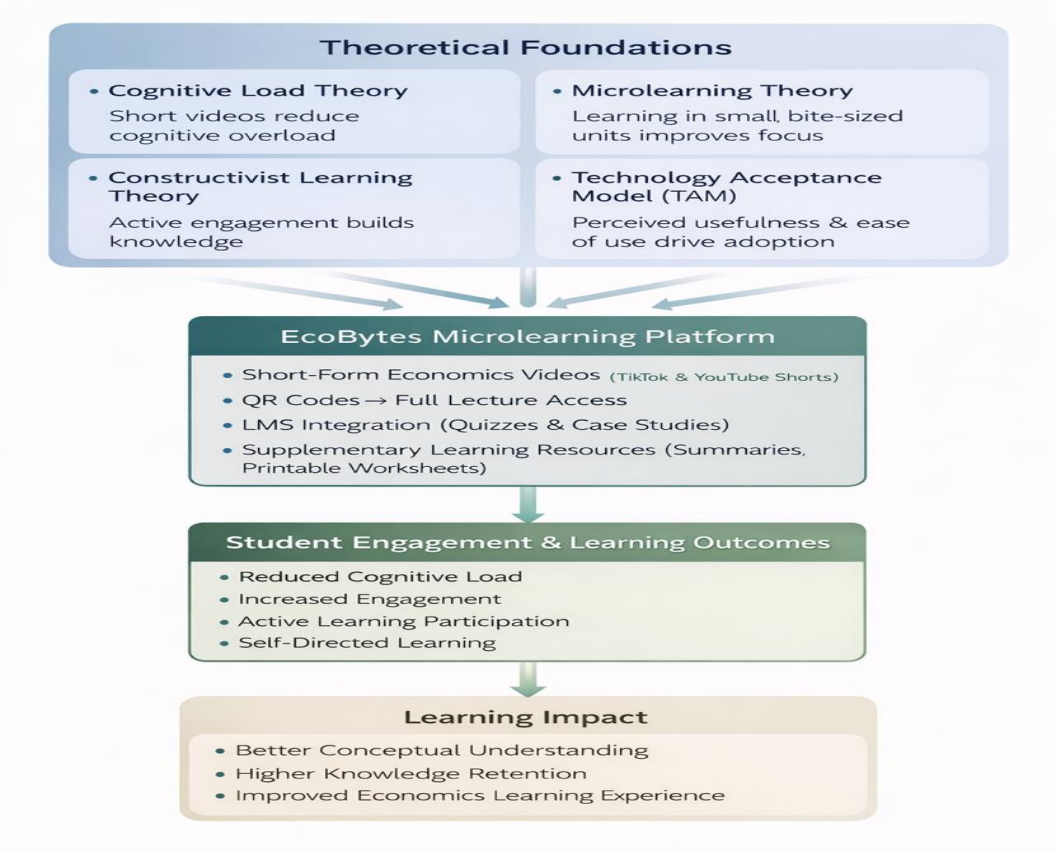
EcoBytes is in line with TAM because it uses platforms like TikTok and YouTube Shorts, which the audience is familiar with and delivers content in a fast-to-access format. This way, students can interact with learning resources using interfaces that are already widely adopted for consuming digital media. The short-video format might also enhance perceived convenience for learners who enjoy flexible, bite-sized study resources.

Integrating Theoretical Perspectives

The theoretical perspectives presented together provide a coherent foundation for EcoBytes. Cognitive Load Theory explains how segmenting information may reduce unnecessary processing demands. Microlearning Theory emphasizes the value of brief and focused learning units. Constructivist Learning Theory emphasizes the need for active engagement with content. TAM explains how perceived usefulness and ease of use may influence students' adoption of digital learning tools

This incorporation of perspectives makes EcoBytes a pedagogically informed approach to delivering economics content in brief-form digital media. The platform combines microlearning, additional learning activities and familiar social media interfaces to create a flexible ecosystem that can complement traditional economics teaching.

Figure 1: Conceptual Framework of the EcoBytes Microlearning Ecosystem



3. Research Methodology

The current study used a quasi-experimental pre-test/post-test design to examine the change in students' economics performance following the EcoBytes learning intervention. This design allows for a comparison of performance before and after an instructional intervention in an educational setting (Creswell & Creswell, 2018).

The participants were undergraduates who used EcoBytes for their course activities. Their learning performance was assessed before and after the intervention using structured assessments. The study was concerned with changes in assessment performance rather than with measures of student engagement, such as behaviour or attitudes.

Five test items (Q2, Q3, Q8, Q13, and Q16) were selected for item-level analysis to identify specific areas of conceptual difficulty since these items covered concepts that students commonly found challenging. Total test scores were also recorded and analysed by score category. This two-level approach allowed the study to describe both changes in errors on particular concepts and more general changes in the distribution of student performance.

Students completed a baseline assessment (pre-test) before the EcoBytes intervention. They took the same or similar assessment (post-test) after using EcoBytes. Pre- and post-intervention changes in performance were identified by comparing the percentage of errors in specific items and the distribution of total scores at the two time points of assessment.

Descriptive statistics were used for data analysis. Errors were expressed as percentages for each item and the distributions of total scores were compared to get some idea of the general changes in performance. This methodological approach adheres to the guidelines offered by Shadish et al. (2002) on program evaluation and causal inference in quasi-experimental designs.

4. Results

The results show an improvement in student learning performance after the intervention of EcoBytes. As shown in Figure 2, the error rates of the selected test items were reduced. For instance, the errors in Q2 were lowered from 12.12% in the pre-test to 6.98% in the post-test and the errors in Q8 fell from 18.18% to 9.30%. The most notable improvements were in Q3 and Q13 where the post-test errors went to zero. The descriptive changes suggest that the intervention might have assisted students in overcoming certain conceptual difficulties, which is consistent with prior research on the potential of well-designed multimedia learning materials in aiding understanding (Clark & Mayer, 2016).

Figure 2: Error rates before and after Ecobytes

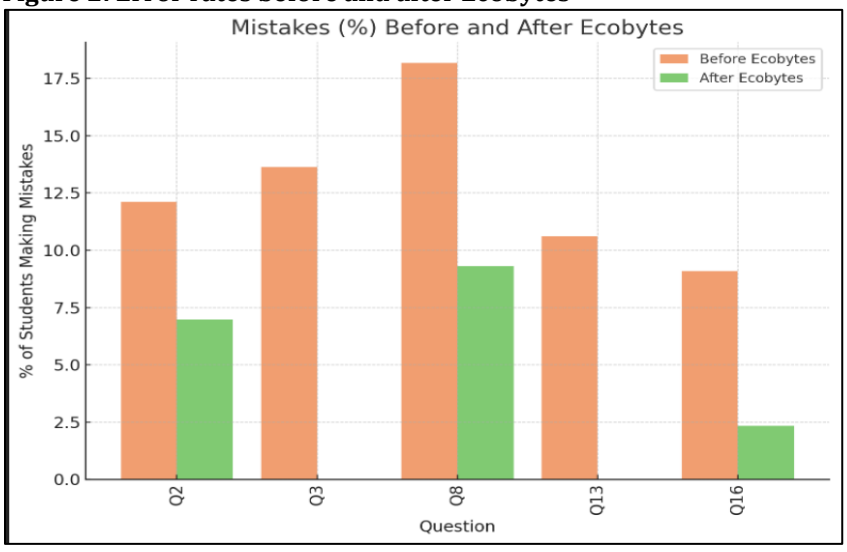
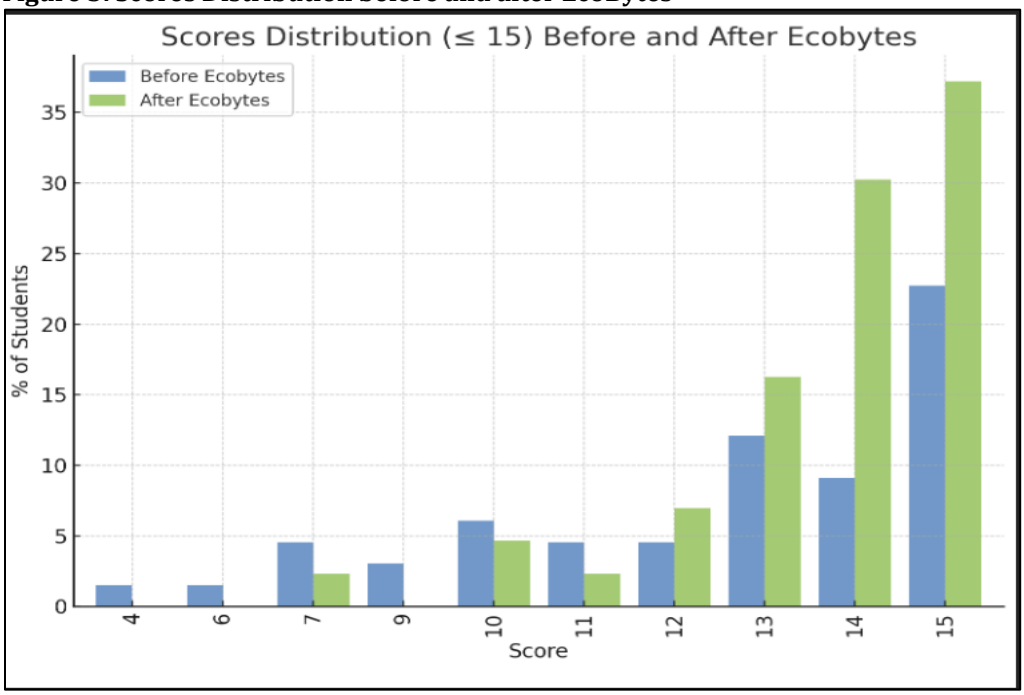


Figure 3 shows overall changes in test performance. The distribution of scores has moved upwards after the intervention. In the post-test distribution, there were no pre-test scores as low as 4, 6 and 9. There was also a decrease in the frequencies of several mid-range scores such as 7, 10 and 11. The proportion of students who scored 12 and above increased. These descriptive patterns suggest that some of the students moved from lower or middle score categories to higher performance categories after the use of EcoBytes. The trend of this change is consistent with previous research reporting improved academic achievement following well-designed digital learning interventions (Bernard et al., 2009).

To summarize, the patterns seen in Figures 2 and 3 suggest lower item-level error rates and an overall higher posttest score distribution following the EcoBytes intervention. Since the analysis is descriptive, these findings are best understood as observed pre-test/post-test improvements rather than statistically significant or causal effects. The findings, however, do lend support to further research into short-form, technology-enhanced learning as a complementary approach to improve conceptual understanding in economics (Laurillard, 2012).

Figure 3: Scores Distribution before and after EcoBytes



Discussion

The results suggest that microlearning tools like EcoBytes can facilitate economics learning by providing students with additional opportunities to access and review course content. The reductions in selected item-level errors and the rightward shift of the post-test score distributions indicate an improvement in learning performance after the intervention. These findings are consistent with the wider literature of flexible and student-centred digital learning environments.

In this study, we did not directly measure student engagement. Therefore, the results do not show that engagement increased because of EcoBytes. However, the platform's visual, short-form nature aligns with literature that indicates that Generation Z learners tend to prefer short, multimedia-rich learning resources. Engagement should thus be considered a theoretically plausible benefit which requires to be directly measured in future research, rather than an outcome demonstrated by the present data.

The improvement in assessment performance observed is also in line with principles from microlearning and Cognitive Load Theory. EcoBytes reduces the information load by breaking economic concepts into smaller and more focused segments to help learners focus on the essential ideas. Cognitive load was not directly measured in the present study, so this explanation should be seen as a theoretically motivated interpretation, rather than a directly tested mechanism.

More generally, EcoBytes shows how familiar social media platforms can be integrated into formal economics education when short-form content is linked to structured learning materials and assessments. The intervention should be seen as a supplementary learning ecosystem, not a substitute for lectures or other course activities. Since the study was based on descriptive pre-test/post-test comparisons and did not directly measure engagement, the results should be interpreted with caution and verified with further research employing stronger comparative designs and direct measures of student experience.

5. Managerial Implications and Recommendations

The study provides real practical implications for higher education institutions, lecturers and students. For universities, EcoBytes demonstrates the potential of social-media-based microlearning as a complementary learning approach alongside traditional teaching. Institutions may consider adding short-form learning resources to existing digital learning environments to enhance flexibility and provide students with more opportunities to review course material. However, claims of engagement should be evaluated by direct measurement in future implementation studies.

For lecturers, EcoBytes demonstrates the value of breaking complicated economics content into short, focused explanations linked to broader learning materials. Short educational videos can reinforce concepts introduced in lectures and contribute to blended learning by enabling students to review difficult concepts at their own pace. They are likely to be most effective when the videos are aligned with well-specified learning outcomes, assessment activities and opportunities for more in-depth application.

EcoBytes provides an easily accessible mobile resource for students that can be used for revision and reinforcement outside the classroom. Self-directed learning is supported by short videos accompanied by quizzes, worksheets and more extensive lecture materials, all while keeping students connected to the formal course structure.

Conclusion

This study explores the design and implementation of EcoBytes, a microlearning ecosystem that uses short digital content to support learning economics. EcoBytes offers brief explanations of economic concepts and connects them to extra learning resources for further research and application through platforms like TikTok and YouTube Shorts.

Employing a quasi-experimental pre-test/post-test design and descriptive analysis, the study found declines in error rates for selected assessment items and an upward shift of overall post-test score distributions. These results reflect an improvement in conceptual performance after the intervention. Results should not be interpreted as statistically significant or definitive causal effects, as no inferential statistical tests were performed. The study did not measure student engagement directly and therefore cannot be reported as an observed outcome.

More broadly, EcoBytes adds to the expanding literature on digital pedagogy by demonstrating how microlearning can be integrated into the teaching of economics using popular short-form video platforms. The approach may also be a useful model in other disciplines where students benefit from short explanations that are linked to structured learning activities and more detailed resources.

Future studies should employ larger samples, comparison or control groups where possible, and inferential statistical analysis to determine the strength of the learning effects observed. Student engagement should also be directly measured with appropriate instruments or behavioral indicators. Future studies might explore knowledge retention, perceived usefulness, ease of use and the application of the approach in other areas of higher education.

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Factors Influencing Consumer Buying Behavior for Foreign Products

Nurfarah Diyana Mohd Firhad[1], *Syed Ashrene Syed Omar[2], Janiffa Saidon[2], Nuryusmawati Mohd Yusof[2], Nor Lelawati Jamaludin[2], Faizah Md Sohid[2], Faizah Mashahadi[2]
[1]BIMB Investment Management Berhad Malaysia
[2]Faculty of Business and Management, Universiti Teknologi MARA, Selangor, Malaysia
Email: farahdiyanafirhad@gmail.com, *ashrene@uitm.edu.my, janiffa@uitm.edu.my, nuryusmawati@uitm.edu.my, norlelawati0019@uitm.edu.my, faiza746@uitm.edu.my, faizahmashahadi@uitm.edu.my
Corresponding Author: Syed Ashrene Syed Omar

Abstract: This study aims to determine the factors that influence consumer buying behavior for foreign products among Malaysian university students. Therefore, a survey of 134 Malaysian university students in Selangor Malaysia was conducted to determine the factors that influence consumer buying behavior. Correlation analysis is used to analyze the data to identify the relationship between the variables. Furthermore, multiple regression analysis is applied to determine the significant factors that affect consumer buying behavior for foreign products among Malaysian university students. The results of the survey suggest that product price, product quality and country of origin are significant factors in explaining consumer buying behavior. This study offers renewed empirical insights that contribute to a new way of thinking about the factors driving consumer buying behavior for foreign products specifically in Malaysia.

Keywords: *Consumer Buying Behavior*, *Product Price, Product Quality, Country of Origin*

1. Introduction and Background

The global marketplace is characterized by a sustained proliferation of foreign products, which fundamentally recalibrates consumer preferences and purchasing behaviors. As international trade continues to expand, discerning the multifaceted drivers of consumer choice ranging from economic factors to psychological predispositions has become a strategic imperative for businesses aiming to maintain relevance and competitive advantage in increasingly saturated markets (Danylenko et al., 2025). Against this backdrop, the Malaysian context provides a fertile ground for analysis; university students represent a particularly pivotal demographic whose distinct consumer styles and decision-making patterns have been the subject of recent academic inquiry (Haron & Chinedu, 2017).

This study aims to identify the key factors that influence consumer buying behavior for foreign products among Malaysian university students. By examining variables such as product price, product quality, and country of origin, this research seeks to provide empirical insights into the decision-making processes of this specific consumer segment. However, it must be acknowledged that consumer decision-making is not always purely rational or predictable; subjective factors, such as emotional responses, brand loyalty, and impulsive behavior, can often override objective assessments of price and quality (Margalit, 2020). Thus, while this research focuses on quantifiable drivers, it recognizes the inherent limitations in predicting behavior solely through traditional analytical frameworks. The findings are expected to contribute to the existing body of knowledge regarding consumer behavior, offering a new perspective on the drivers of consumer buying behavior for foreign products in Malaysia.

2. Literature Review

Consumer buying behavior: Consumer buying behavior encompasses the intricate psychological, social, and economic processes individuals undergo when selecting, purchasing, and utilizing products to satisfy their needs (Feyerlein, 2017). A deep understanding of these behaviors is critical for businesses operating in globalized markets, as it provides the analytical foundation necessary to align product offerings with specific consumer preferences such as price sensitivity, quality perceptions, and attitudes toward the country of origin, thereby enabling firms to effectively navigate the complexities of foreign product integration and secure a competitive edge (Danylenko et al., 2025). However, it is important to acknowledge that consumer decision-making is not always purely rational or predictable, subjective emotional responses, brand loyalty, and

impulsive behavior can often override objective assessments of price and quality, thereby limiting the predictive power of traditional analytical models.

Product price: Product price is a critical determinant in consumer decision-making, particularly regarding foreign products. Price sensitivity frequently dictates purchase intentions, as consumers assess the affordability and perceived value of international goods against local alternatives (Danylenko et al., 2025). While price is often viewed through a rational lens, it is important to acknowledge that subjective perceptions and emotional factors can influence how consumers weigh price against other attributes, such as quality (Feyerlein, 2017). However, product price is not always the paramount factor; many consumers prioritize quality or brand reputation over affordability to mitigate purchase risk (Zeeshan, 2013). In certain market segments, higher prices may even be perceived as an indicator of superior quality, effectively neutralizing price sensitivity as the primary driver of purchase intention. Indeed, price remains an important extrinsic cue, its trade-offs with global and local product attributes can influence consumers' willingness to pay and purchasing preferences (Davvetas et al., 2022). Despite these complexities, product price remains a fundamental metric for establishing competitive positioning for global brands.
H1: Product price has a significant relationship with consumer buying behavior.

Product quality: Product quality constitutes a pivotal factor in assessing purchase intentions for foreign goods (Haque et al., 2015). Consumers often prioritize high-quality offerings over price considerations as a strategy to fulfill their requirements while simultaneously mitigating the risks associated with international products. Empirical evidence supports this, as quality serves as a critical mechanism for establishing competitive advantage (Azzahra & Kusumawati, 2023). Moreover, studies have shown that perceived quality acts as a central mediator, bridging the gap between a brand's country of origin and the consumer's ultimate decision to purchase (Prahiawan et al., 2021). Indeed, research indicates that consumer purchasing intentions are fundamentally dependent upon product quality (Haque et al., 2015). However, product quality is not always the principal factor, in certain market segments, consumers may prioritize affordability or brand reputation over quality to mitigate purchase risk. In some instances, price-sensitive consumers may perceive lower prices as sufficient to meet their needs, thereby reducing the influence of superior quality on purchase intention.
H2: Product quality has a significant relationship with consumer buying behavior.

Country of origin: Country of origin serves as a significant heuristic cue that influences consumer perception and purchase intention for foreign products (Prahiawan et al., 2021). Consumers often utilize a product's origin to infer quality and reliability, particularly when direct product experience is limited (Caruana, 1996). While a favorable country image can bolster brand equity and drive consumer preference, negative perceptions or localized ethnocentrism can create significant barriers to market entry (Haque et al., 2015). However, it is essential to recognize that the influence of country of origin is not absolute; consumers frequently weigh origin against other critical variables, such as price sensitivity and perceived product quality, in a complex decision-making process (Davvetas et al., 2022). Conversely, some suggest that the reliance on country of origin as a primary cue is becoming less absolute, particularly in globalized markets where strong global branding and specific product performance can influence perceptions (Aboagye & Haozhen, 2024). In such segments, consumers may prioritize brand reputation or intrinsic functional attributes over the country of origin, potentially reducing its predictive power regarding purchase intent.
H3: Country of origin has a significant relationship with consumer buying behavior.

3. Methodology

A survey was conducted amongst Malaysian university students residing in Selangor Malaysia. Using a quantitative study, a questionnaire was used to determine the factors that influence consumer buying behavior. Therefore, a quantitative approach was used to conduct the study. Overall, 200 questionnaires were disseminated and 134 questionnaires were meaningful for analysis purposes. A total of 134 respondents is sufficient to conduct analysis (Faul et al., 2009). The questionnaire was the main instrument for data collection. The questionnaire covered five sections. The first section was intended to gather the demographic profile of the respondents. The second section assessed the product price. Next, the third section assessed product quality. The fourth section measured country of origin. Finally, the fifth section assessed consumer buying behavior items. A five-point Likert scale, where 1= strongly disagree to 5 = strongly agree was used to measure

the questionnaire items. Correlation coefficients were used to recognize the relationship between the dependent variables and independent variables. Furthermore, multiple regression was applied to determine the significant factors that affect consumer buying behavior.

4. Results

Reliability Analysis: Table 1 presents the reliability analysis for both independent variables and dependent variables. The variables are product price, product quality and country of origin, as well as consumer buying behavior.

Table 1: Reliability Analysis

Variables	Cronbach's Alpha	Reliability Analysis (Sekaran & Bougie, 2013)
Consumer buying behavior	.658	Moderate
Product price	.650	Moderate
Product quality	.895	Good
Country of origin	.674	Moderate

The Cronbach's Alpha value for consumer behavior is 0.658, signifying a moderate and reliable result. In addition, Cronbach's Alpha for product price is 0.650, suggesting a moderately reliable outcome that remains within the satisfactory range. The value of Cronbach's Alpha for product quality is 0.895, indicating a good and reliable result. Lastly, the value of Cronbach's Alpha for country of origin is 0.674, showcasing a moderate and reliable outcome.

Correlation Analysis: Table 2 shows the correlation analysis to prove the strength of a linear association between variables. The coefficient of correlation is applied to measure the strength of the correlation between variables.

Table 2: Correlation Analysis

Dependent Variable	Independent Variable		
	Product Price	Product Quality	Country of Origin
Consumer buying behavior	.623**	0.599**	.580**

(**p<0.01)

The correlation analysis interpretation was based on Guilford's Rule of Thumb (Guilford, 1973). The result found a moderate relationship between consumer buying behavior and product price ($r = 0.623$, $p < 0.01$). There was a moderate relationship between consumer buying behavior and product quality ($r = 0.599$, $p < 0.01$). Finally, there was a moderate relationship between consumer behavior and country of origin ($r = 0.580$, $p < 0.01$).

Regression Analysis: Multiple regression analysis was conducted to further investigate the significant relationship between the dependent variables and independent variables. Table 3 shows the results of multiple regression.

Table 3: Multiple Regression Analysis

Independent Variable	Dependent Variable: Consumer buying behavior
Product price	.224*
Product quality	.323*
Country of origin	.246*
R^2	.466
F	37.875*

(*p<0.05)

From multiple regression analysis, product price was identified as a significant factor determining consumer buying behavior ($B = 0.224$, $p < 0.05$), thus H1 is supported. Next, product quality was recognized as a significant factor determining consumer buying behavior ($B = 0.323$, $p < 0.05$), therefore H2 is supported. Finally, country of origin was identified as a significant factor determining consumer buying behavior, hence H3 is supported. Next, from multiple regression procedures, the model consisting of consumer buying behavior, product price, product quality and country of origin was found to be significant ($F = 37.875$, $p < 0.05$) and the $R2 = 0.466$ explaining 46.6% of the variance in consumer buying behavior.

Discussion: This research aims to gain a better understanding of the relationship between factors namely product price, product quality, country of origin and consumer buying behavior for foreign products. The results of this research were obtained through various statistical analyses, correlation analysis, Cronbach's Alpha, and regression analysis. The empirical results of this study substantiate the proposed hypotheses, confirming that product price, product quality, and country of origin serve as significant determinants of consumer buying behavior among university students in Selangor, Malaysia. The regression analysis further highlighted the relative importance of these factors, with all hypotheses being supported. Notably, product quality emerged as the strongest predictor of buying behavior consistent with findings regarding the importance of quality in consumer decisions (Zeeshan, 2013). This aligns with previous research that identified a positive association between quality and purchasing intentions (Tariq et al., 2013). While product price and country of origin were also statistically significant, the study model indicates that these factors account for 46.6% of the variance in consumer buying behavior. This suggests that while these variables are influential, the complexity of consumer decision-making is likely to involve additional factors, warranting further exploration in future studies.

Managerial Implications and Recommendations: The empirical findings offer actionable insights for marketers and business strategists targeting the student demographic in Malaysia. Primarily, since product quality emerged as the most influential factor, management must prioritize consistent quality control and transparent communication of product features to reduce consumer uncertainty and perceived risk (Lee et al., 2019). Marketing campaigns should highlight these quality attributes as a primary competitive advantage to drive purchase intentions (Tabish et al., 2025). Although price and country of origin are significant, they function as supporting decision criteria. Therefore, instead of competing exclusively on price, firms should employ value-based pricing strategies that reflect the quality of their offerings. Additionally, businesses should capitalize on positive country of origin associations where applicable. If the country of origin is not a primary strength, companies should focus on building strong brand equity and signaling quality to transcend geographic origin limitations (Magnusson et al., 2008). However, it is essential to note that for highly price-sensitive segments, an exclusive focus on quality might be limiting, in contexts where economic constraints dictate purchasing power, aggressive pricing and promotional strategies may temporarily outweigh qualitative attributes in the decision-making process. Overall, a balanced strategy that prioritizes quality while maintaining competitive pricing and strategic brand positioning is recommended to effectively capture the target market.

5. Conclusion

In conclusion, this research confirms that product price, product quality, and country of origin are significant determinants of consumer buying behavior among university students in Selangor, Malaysia. The results substantiate the study's hypotheses, revealing that while price and country of origin contribute to consumer decision-making, product quality serves as the most potent predictor of purchasing intentions (Lee et al., 2019; Tariq et al., 2013; Zeeshan, 2013). Consequently, marketers targeting this demographic should prioritize high-quality standards and transparent product communication over aggressive, price-focused competition. An effective market strategy requires integrating quality signaling with value-based pricing and strategic branding to navigate the complexities of consumer behavior and address potential geographic limitations (Magnusson et al., 2008). Moving forward, businesses that adopt this holistic approach are better positioned to foster long-term customer loyalty and achieve a competitive advantage in the student market.

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Knowledge-Based and Social Determinants of Environmental Performance Among Young Adults in Klang Valley: The Mediating Role of Green Innovation Practice

Dellorinna Icha Anak Tang[1], *Ramita Abdul Rahim[2], Siti Fazilah Hamid[2], Nur Fatin Izzati Jeffri[3]
[1]ICHA Enterprise, 1st Floor Gelanggang Kenyalang, Kapit Sarawak, Malaysia
[2]Faculty of Business and Management, Department of Technology and Supply Chain Management Studies, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia
[3]UNITAR College Sg. Petani, Plot A-G, Jalan Kampung Baru, 08000 Sungai Petani, Kedah, Malaysia
Email: *ramita@uitm.edu.my
Corresponding Author: Dr Ramita Abdul Rahim

Abstract: Environmental sustainability has become a major global concern, particularly among young adults who play an important role in shaping future environmental outcomes. This study examines the influence of knowledge-based and social determinants on environmental performance among young adults in Klang Valley, Malaysia, with Green Innovation Practice as a mediating variable. Specifically, this study investigates the effects of Green Knowledge, Environmental Knowledge Learning, Peer Pressure, and Social Media Influence on Environmental Performance. This study is grounded in the Ability–Motivation–Opportunity (AMO) Theory. A quantitative research approach was employed using a structured questionnaire distributed to 160 young adults aged 18 to 35. Data were analyzed using Partial Least Squares Structural Equation Modelling (PLS-SEM). The findings indicate that while Green Knowledge and Social Media Influence directly enhance Environmental Performance, Environmental Knowledge Learning and Peer Pressure do not have a direct effect. Furthermore, Green Innovation Practice serves as a critical behavioral mechanism that fully mediates the impact of Environmental Knowledge Learning and Peer Pressure, and partially mediates the effect of Social Media Influence on Environmental Performance. It does not, however, mediate the relationship for Green Knowledge. Finally, these findings extend the AMO Theory within the environmental context, providing policymakers and educators with clear, evidence-based strategies to drive actual environmental performance.

Keywords: *Environmental Performance, Green Knowledge, Environmental Knowledge Learning, Peer Pressure, Social Media Influence, Green Innovation Practice*

1. Introduction

Environmental problems are escalating globally with regard to issues including climate change, resource degradation, and pollution, which requires that individuals, organizations, and government bodies transition toward more environmentally friendly practices (Demir et al., 2025; Javed et al., 2026). As an individual's primary method to achieve environmental improvement is through changing his or her daily behaviors by decreasing his or her generation of waste, decreasing energy consumption, and transitioning to environmentally friendly lifestyle choices they contribute to the long-term sustainability of ecosystems (Hejazi et al., 2023; Asmar et al. 2022). Since young adults are both significant consumer groups and future decision-making entities their current environmental attitudes and behaviors will have significant implications regarding the future of sustainability (Zhang et al., 2024; Bai & Lyu, 2023).

Despite the increasing environmental awareness among young adults, research has demonstrated empirically that environmental awareness may not always result in pro-environmental behavior. Young adults often face psychological, motivational, and social obstacles that prevent them from making changes in their behavior (Su et al., 2020). Research related to environmentalism in Malaysia — especially within cities similar to the Klang Valley — has been limited due to a lack of comprehensive models that include social influence factors, knowledge-related factors, and green innovation factors in a holistic manner. This study seeks to fill this gap by investigating the relationships between Green Knowledge (GK), Environmental Knowledge Learning (EKL), Peer Pressure (PP), Social Media Influence (SMI), and Environmental Performance (EP); also examining the mediational effects of Green Innovation Practices (GIP) to determine how environmental awareness and social influences can lead to environmental performance among young adult populations in the Klang Valley region.

2. Literature Review

Knowledge-Based Determinants

Green Knowledge (GK). Green Knowledge (GK) has long been recognized as a pivotal factor in fostering pro-environmental behavior. GK refers to an individual's comprehension of environmental issues, eco-friendly products, and sustainable practices, encompassing an awareness of how daily actions impact the natural environment (Zhang et al., 2024). Individuals possessing higher levels of GK typically exhibit greater awareness of pressing ecological crises, such as climate change, pollution, and resource depletion, which consequently heightens their concern for environmental protection. Previous studies such as Zhang et al. (2024), Masri et al. (2017) and xxx underscored that GK does more than raise awareness; it significantly enhances an individual's capacity to evaluate sustainable options, thereby bolstering their confidence to implement green practices. This indicates that GK is instrumental in facilitating informed decision-making regarding sustainability. When individuals possess a robust understanding of environmental issues, they are more inclined to purchase eco-friendly products, minimize waste, and engage in conservation efforts. Furthermore, GK significantly shapes environmental attitudes and values. An understanding of the long-term ecological consequences of human action fosters positive attitudes toward sustainability, which subsequently guides behavioral intentions and improves overall environmental performance (Hejazi et al., 2023). For young adults, who are highly receptive to information from educational institutions and digital media, GK is a critical independent variable for elucidating disparities in environmental performance.

Environmental Knowledge Learning (EKL). While GK represents the possession of information, Environmental Knowledge Learning (EKL) denotes the continuous, dynamic process through which individuals acquire, develop, and apply environmental knowledge. EKL distinguishes itself from general awareness by emphasizing ongoing learning through formal education, informal experiences, and persistent exposure to environmental discourse (Su et al., 2020). Su et al. (2020) highlighted that individuals who actively engage in EKL are more likely to deepen their comprehension of complex ecological issues, thereby cultivating a stronger commitment to environmental preservation. Through continuous education, individuals become more adept at understanding the ecological footprint of their actions, leading to a highly responsible culture and lifestyle choices (Pham et al., 2019). This indicates that EKL not only facilitates the acquisition of knowledge but also fosters enduring pro-environmental attitudes and behavioral inclinations. For young adults constantly exposed to educational content and environmental campaigns, EKL serves as a crucial determinant for understanding behavioral variations in environmental performance.

Social Determinants

Peer Pressure (PP). In addition to cognitive factors, social environments exert a profound influence on environmental behavior. Peer Pressure (PP) refers to the influence that friends, peers, and social groups have on an individual's attitudes and actions. In the context of sustainability, PP represents the degree to which an individual's social circle encourages or discourages eco-friendly behaviors. Rahnama Haratbar et al. (2023) emphasized that peer influence significantly impacts the development of sustainable attitudes, particularly among young adults who are highly susceptible to social norms. PP operates through social expectations and the desire for social conformity. When individuals observe their peers prioritizing environmental protection and engaging in sustainable actions, they are more likely to adopt similar behaviors to gain social approval. This normative pressure can successfully drive positive behaviors such as recycling and waste reduction. Conversely, weak environmental norms within a peer group may inhibit the adoption of sustainable practices. Because young adults spend considerable time within close-knit social networks, PP functions as a powerful social mechanism shaping their environmental actions.

Social Media Influence (SMI). The digital era has elevated Social Media Influence (SMI) as a primary determinant of environmental behavior. SMI refers to the impact that content exposure and social interactions on digital platforms (e.g., Instagram, TikTok, Facebook) have on individuals' perceptions and actions regarding sustainability. Sun and Xing (2022) highlighted that social media has emerged as a vital medium for disseminating environmental information and shaping users' behavioral intentions. SMI operates through content exposure, online engagement, and digital social interaction. Frequent exposure to environmental

content educates users on sustainable living, while likes, shares, and endorsements from influencers signal social acceptability. This digital validation makes environmental responsibility appear increasingly important, thereby changing societal expectations. For young adults, whose worldview is heavily influenced by online communities and trending content, SMI is a profound catalyst for adopting environmentally responsible behaviors.

Green Innovation Practice (GIP) as a Behavioral Mechanism. Green Innovation Practice (GIP) refers to the degree to which individuals incorporate innovative, eco-friendly behaviors into their daily routines, such as adopting green technologies and supporting sustainable practices. Wang et al. (2021) characterized GIP as pragmatic initiatives that convert environmental consciousness into concrete actions, highlighting that GIP embodies the *behavioral application* of green concepts rather than mere cognitive awareness. GIP is essential for bridging the intention-behavior gap. Individuals may possess extensive environmental knowledge and experience positive social pressure, yet these factors do not always culminate in real behavioral change. GIP acts as the mechanism through which knowledge and social motivation are translated into tangible actions, such as altering consumption patterns and supporting green initiatives (Anwar et al., 2020; Paillé et al., 2020). Leveraging green human resource practices to achieve environmental sustainability. For young adults, who are generally more receptive to experimenting with new ideas and technologies, GIP serves as an essential framework for understanding how cognitive and social influences materialize into tangible environmental behavior.

Environmental Performance (EP). Environmental Performance (EP) represents the dependent variable in this study, defined as the extent to which individuals engage in actions that mitigate negative environmental impacts, such as reducing waste, conserving resources, and minimizing pollution. Hejazi et al. (2023) defined EP as the outcome of individuals' environmental consciousness and their active efforts to safeguard the environment. EP is increasingly prioritized as an outcome variable in sustainability research because cumulative individual actions generate significant macro-environmental effects. Common indicators of robust EP include the reduction of single-use plastics, energy conservation, and active participation in environmental initiatives. Enhancing EP among young adults is particularly critical, as their current daily habits and lifestyle choices will dictate long-term ecological sustainability.

Hypothesis Development

The Direct Effects on Environmental Performance. Knowledge is essential in shaping pro-environmental attitudes. GK provides the awareness necessary to recognize the ecological consequences of daily actions, which encourages responsible environmental stewardship (Zhang et al., 2024). Consequently, GK is widely regarded as a crucial prerequisite for enhancing EP (Hejazi et al., 2023). Similarly, EKL facilitates a continuous deepening of this understanding, ensuring that knowledge evolves into enduring behavioral patterns (Su et al., 2020).

H1: Green Knowledge has a significant positive relationship with Environmental Performance.

H2: Environmental Knowledge Learning has a significant positive relationship with Environmental Performance.

Social environments also establish normative rules for behavior. PP enhances an individual's motivation to pursue sustainable actions through the psychological reward of social approval (Rahnama Haratbar et al., 2023; Sheikh et al., 2024). Concurrently, SMI reinforces these norms digitally, where online social validation encourages the consistent adoption of eco-friendly habits (Sun & Xing, 2022; Hejazi et al., 2023).

H3: Peer Pressure has a significant positive relationship with Environmental Performance.

H4: Social Media Influence has a significant positive relationship with Environmental Performance.

The Direct Effects on Green Innovation Practice. To successfully adopt innovative green behaviors, individuals require both the requisite knowledge and social motivation (Yong et al., 2020). GK and EKL provide the mental framework needed to evaluate eco-friendly solutions and the confidence to embrace novel sustainable practices (Zhang et al., 2024). Furthermore, PP and SMI supply the social validation necessary to encourage individuals to experiment with new green technologies and integrate them into their daily routines (Rahnama Haratba et al., 2023; Wang et al., 2021).

H5: Green Knowledge has a significant positive relationship with Green Innovation Practice.

H6: Environmental Knowledge Learning has a significant positive relationship with Green Innovation Practice.
H7: Peer Pressure has a significant positive relationship with Green Innovation Practice.
H8: Social Media Influence has a significant positive relationship with Green Innovation Practice.

The Mediating Role of Green Innovation Practice. When individuals actively adopt GIP such as changing consumption habits and experimenting with sustainable alternatives they demonstrate higher levels of EP (Wang et al., 2021).
H9: Green Innovation Practice has a significant positive relationship with Environmental Performance.

Recent sustainability research increasingly utilizes mediation models to elucidate how knowledge and social factors translate into tangible behavioral outcomes. Rather than assuming a direct, frictionless path from awareness to performance, researchers emphasize the necessity of behavioral mechanisms. While GK, EKL, PP, and SMI motivate individuals to seek sustainable solutions (Zhang et al., 2024; Su et al., 2020; Rahnama Haratbar et al., 2023; Sun & Xing, 2022), these influences may not produce improved environmental outcomes without the active execution of green practices. Therefore, GIP functions as the crucial conduit converting cognitive, psychological, strategic pathway and social inputs into concrete sustainability outcomes (Hejazi et al., 2023; Alharethi et al., 2026).
H10: Green Innovation Practice mediates the relationship between Green Knowledge and Environmental Performance.
H11: Green Innovation Practice mediates the relationship between Environmental Knowledge Learning and Environmental Performance.
H12: Green Innovation Practice mediates the relationship between Peer Pressure and Environmental Performance.
H13: Green Innovation Practice mediates the relationship between Social Media Influence and Environmental Performance.

Underpinning Theory

The Ability-Motivation-Opportunity (AMO): This theory suggests that an employee's job performance can be influenced by three factors: ability, motivation, and opportunity. Bos-Nehles et al. (2013) further suggest that employees will perform at higher levels if they have the relevant knowledge and skills (ability), there are motivating factors inside or outside of the organization that influence behavior (motivation), and they have the right conditions or ways to implement what they intend to do (opportunity). The AMO theory serves as a strong theoretical basis for this study; it enables us to understand how both cognitive abilities and social determinants can facilitate the environmental performance of young adults. Within the structure of this research framework, this study maps the independent and mediating variables to each dimension of the AMO theory.

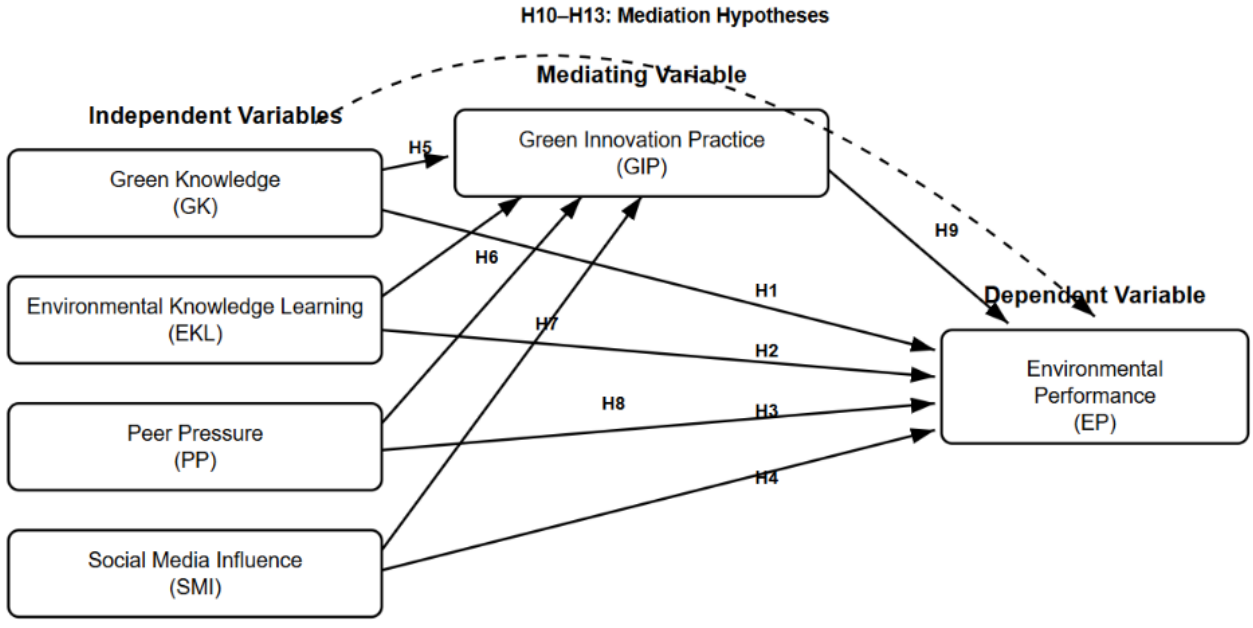
Ability (Knowledge and Skills): Ability is defined as being related to one's level of knowledge or skill. This study measures ability through two concepts: Green Knowledge (GK) and Environmental Knowledge Learning (EKL). When young adult learners possess basic knowledge about environmental topics, and continue to develop new knowledge, they will be able to assess environmental problems and find effective, long-term solutions (Su et al., 2020; Zhang et al., 2024).

Motivation (Incentives and Drive): Motivation is defined as incentives or drive. The definition of motivation is measured by Peer Pressure (PP) and Social Media Influence (SMI). The social pressure from peers, adherence to peer norms, and exposure to environmental content on social media serve as powerful psychological drivers that lead young adults to engage in and maintain environmentally friendly behaviors (Rahnama Haratbar et al., 2023; Sun & Xing, 2022).

Opportunity (Avenues for Action): This study defines opportunity as the avenue for taking action and opportunity measures as Green Innovation Practices (GIP). GIP provides the framework for behavior and practical means for young adults to apply their knowledge and motivation to real-world situations (Wang et al., 2021).

Overall, the AMO theory provides a comprehensive theoretical framework for the proposed research model. The AMO theory also supports the main hypothesis of this study that Young Adults' Environmental Performance (EP) is optimal when they have sufficient cognitive capacity (knowledge) (Green Knowledge [GK] and Environmental Knowledge Learning [EKL]), sufficient social motivation (Peer Pressure [PP] and Social Media Influence [SMI]), and enough opportunities to engage in green innovation practices (GIP) (Hejazi et al., 2023). Importantly, the AMO theory demonstrates that ability and motivation need to be converted into a form of practice to produce measurable environmental performance.

Figure 1: Conceptual Framework of the Relationship Between Green Knowledge, Environmental Knowledge Learning, Peer Pressure, Social Media Influence, Green Innovation Practice and Environmental Performance.



Notes:

H1–H4 = Direct effects of Independent Variables on Environmental Performance (EP).
H5–H8 = Direct effects of Independent Variables on Green Innovation Practice (GIP).
H9 = Direct effect of Green Innovation Practice (GIP) on Environmental Performance (EP).
H10–H13 = Mediating effects of GIP between Independent Variables and EP.

Source:

Meng Zhang et al., 2024;
Xiaofeng Su et al., 2020;
Hassan Rahnama Haratbar et al., 2023;
Yongbo Sun et al., 2022;
Haijun Wang et al., 2021;
Mohammed Taj Hejazi et al., 2023.

Figure 1 presents the conceptual framework developed for this study. The framework proposes that Green Knowledge (GK), Environmental Knowledge Learning (EKL), Peer Pressure (PP), and Social Media Influence (SMI) directly influence Environmental Performance (EP) (H1–H4). In addition, the framework hypothesizes that Green Innovation Practice (GIP) mediates the relationships between the four independent variables and environmental performance (H5–H8). A direct relationship between Green Innovation Practice and Environmental Performance is also proposed (H9). The framework is grounded in the premise that knowledge, learning, and external social influences encourage the adoption of green innovation practices, which subsequently enhance organizational environmental performance. Accordingly, Green Innovation Practice is expected to function as an important mechanism through which organizational and social factors translate into improved environmental outcomes. The conceptual framework was developed based on previous empirical studies (Meng Zhang et al., 2024; Su et al., 2020; Rahnama Haratbar et al., 2023; Sun et al., 2022; Wang et al., 2021; Hejazi et al., 2023).

3. Methodology

Research Design and Sampling
This study employed a quantitative, non-experimental correlational research design utilizing a cross-sectional survey methodology. This design was selected as it effectively facilitates the examination of the strength and direction of relationships between multiple variables at a specific point in time without the manipulation of variables (Creswell & Creswell, 2023; Sekaran & Bougie, 2020).

The target population for this research comprised young adults residing in the Klang Valley, Malaysia. This demographic was purposefully targeted because young adults are significant consumers who are heavily influenced by digital platforms and social dynamics, making them ideal subjects for studying environmental awareness and sustainable behaviors. Data were gathered using a non-probability purposive sampling technique to ensure respondents met specific inclusion criteria: (1) aged between 18 and 35 years, (2) currently residing in the Klang Valley, and (3) possessing fundamental awareness or experience regarding environmental issues.

To determine an adequate sample size, a statistical power analysis was conducted using G*Power software. Based on parameters of a 0.05 significance level (α), a statistical power of 0.95, an effect size of 0.15, and five predictors within the structural model, the minimum required sample size was calculated to be 138 respondents. The actual data collection exceeded this requirement, yielding 160 valid responses, thereby ensuring robust statistical power and reliable results (Hair et al., 2022).

Research Instrument
Data were collected via a structured, self-administered online questionnaire. The instrument utilized established measurement scales adapted from prior validated empirical studies to ensure accuracy and contextual relevance. All construct items were measured using a 7-point Likert scale, ranging from 1 ("Strongly Disagree") to 7 ("Strongly Agree").

The questionnaire was divided into specific sections:
Demographic Background: Captured data on gender, age, race, location, and educational attainment.
Green Knowledge (GK): Adapted from Meng Zhang et al. (2024), consisting of 4 items assessing respondents' comprehension of environmental issues and sustainable products.
Environmental Knowledge Learning (EKL): Adapted from Su et al. (2020), comprising 3 items evaluating the continuous acquisition of environmental information.
Peer Pressure (PP): Adapted from Rahnama Haratba et al. (2023), including 4 items measuring the influence of friends and family on sustainable behaviors.
Social Media Influence (SMI): Adapted from Sun and Xing (2022), consisting of 4 items examining the impact of digital environmental content on awareness and actions.
Green Innovation Practice (GIP): Adapted from Wang et al. (2021), featuring 4 items measuring the practical adoption of eco-friendly products and technologies.
Environmental Performance (EP): Adapted from Hejazi et al. (2023), comprising 4 items assessing daily environmental responsibility, such as waste reduction and resource conservation.

Prior to full-scale data collection, content validity was verified by academic experts, and a pilot test involving 22 respondents was conducted. The pilot test confirmed the clarity of the items and demonstrated excellent internal consistency, with all Cronbach's Alpha values exceeding the 0.70 threshold (e.g., GK = 0.933, GIP = 0.905, EP = 0.908), indicating that the instrument was highly reliable and required no significant alterations.

Data Collection Procedure
Data collection was executed from November to December 2025 using an online survey distributed via social media platforms (e.g., WhatsApp, Instagram, Facebook) and university networks. Online distribution was chosen to maximize reach, accelerate response times, and reduce missing data by implementing mandatory response fields (Creswell & Creswell, 2023). A screening question was included at the beginning of the survey to ensure respondents met the inclusion criteria. Participation was strictly voluntary, and all responses were kept anonymous and confidential in adherence to ethical research standards.

Data Analysis Strategy

The collected data were analyzed using IBM SPSS Statistics and SmartPLS software. Initially, SPSS was utilized for data screening identifying missing values and unengaged responses and for generating descriptive statistics to summarize the demographic profile of the respondents (Sekaran & Bougie, 2020).

Subsequently, inferential analysis was conducted using Partial Least Squares Structural Equation Modelling (PLS-SEM) via SmartPLS. PLS-SEM was selected for its robust capability to simultaneously analyze complex relationships among multiple latent constructs, including mediation effects (Hair et al., 2022). The analysis followed a systematic two-stage approach:

Measurement Model Assessment: Evaluated internal consistency reliability (via Cronbach's Alpha and Composite Reliability), convergent validity (via Average Variance Extracted, AVE > 0.50), and discriminant validity (via the Fornell-Larcker criterion and Heterotrait-Monotrait Ratio, HTMT < 0.90) (Hair et al., 2022).

Structural Model Assessment: Tested the proposed hypotheses by evaluating path coefficients, statistical significance via bootstrapping, the coefficient of determination (R^2), effect sizes (f^2), and the model's predictive relevance (Q^2) (Hair et al., 2022).

4. Findings and Discussion

This section presents the empirical findings of the study, which investigated the interconnections among Green Knowledge (GK), Environmental Knowledge Learning (EKL), Peer Pressure (PP), Social Media Influence (SMI), Green Innovation Practice (GIP), and Environmental Performance (EP). Data analysis was conducted using IBM SPSS for initial data screening and descriptive statistics, followed by Partial Least Squares Structural Equation Modelling (PLS-SEM) via SmartPLS to assess the measurement and structural models.

Data Screening and Demographic Profile

A total of 160 valid responses were collected from young adults in the Klang Valley, yielding a 100% response rate with no missing data. This sample size surpasses the minimum requirement of 138 respondents determined via G*Power analysis, confirming its adequacy for PLS-SEM. Skewness and kurtosis values for all measurement items ranged between -2 and +2, indicating that the data were normally distributed and suitable for multivariate analysis (Hair et al., 2022).

The demographic profile revealed a balanced gender distribution comprising 52.5% males and 47.5% females. The majority of respondents were aged 25–29 (45.0%), followed by 18–24 (34.4%). The sample reflected a multicultural urban demographic. Educationally, the respondents were highly qualified, with the majority holding a Bachelor's Degree (29.4%), a Diploma (27.5%), or a Master's Degree (26.9%).

Table 1: Demographic profile of respondents

	N	%
Gender		
Male	84	52.5
Female	76	47.5
Age		
18 – 24	55	34.4
25 – 29	72	45.0
30 - 35	33	20.6
Race		
Malay	50	31.3
Chinese	30	18.8
Indian	18	11.3
Iban Dayak	46	28.7
Others	16	10.0
Education Level		
Secondary School	17	10.6

Diploma	44	27.5
Bachelor's Degree	47	29.4
Master's Degree	43	26.9
Doctoral Degree	9	5.6

Measurement Model Assessment

The measurement model was evaluated based on indicator reliability, internal consistency, and convergent and discriminant validity.

Reliability and Convergent Validity.

Indicator reliability was confirmed as all outer loadings ranged from 0.757 to 0.914, exceeding the recommended 0.70 threshold (Hair et al., 2022). Internal consistency was established, with both Cronbach's Alpha and Composite Reliability (CR) values for all constructs well above 0.70. Convergent validity was achieved as the Average Variance Extracted (AVE) for all constructs exceeded the 0.50 threshold, confirming that each construct explains more than half of the variance in its indicators as shown in Table 2.

Table 2: Reliability and Convergent Validity

Construct	Item	Outer Loading	Cronbach's α	Composite Reliability (CR)	AVE
Environmental Knowledge Learning (EKL)	EKL1	0.848	**0.804**	**0.884**	**0.718**
	EKL2	0.844			
	EKL3	0.849			
Environmental Performance (EP)	EP1	0.845	**0.890**	**0.924**	**0.752**
	EP2	0.866			
	EP3	0.875			
	EP4	0.881			
Green Innovation Practice (GIP)	GIP1	0.877	**0.915**	**0.940**	**0.797**
	GIP2	0.914			
	GIP3	0.908			
	GIP4	0.873			
Green Knowledge (GK)	GK1	0.757	**0.812**	**0.873**	**0.633**
	GK2	0.781			
	GK3	0.814			
	GK4	0.828			
Peer Pressure (PP)	PP1	0.761	**0.825**	**0.884**	**0.656**
	PP2	0.792			
	PP3	0.842			
	PP4	0.841			
Social Media Influence (SMI)	SMI1	0.802	**0.841**	**0.893**	**0.677**
	SMI2	0.848			
	SMI3	0.811			
	SMI4	0.830			

Discriminant Validity

Discriminant validity was initially assessed using the Fornell-Larcker criterion shown in Table 3. The square root of the AVE for each construct was greater than its highest correlation with any other construct, fulfilling the criterion. Additionally, the Heterotrait-Monotrait Ratio (HTMT) was evaluated and shown in Table 4. While some HTMT values marginally exceeded the strict 0.90 threshold (e.g., GIP and EP at 0.902; EKL and SMI at 0.901), this is theoretically acceptable in PLS-SEM when constructs are conceptually intertwined and supported by robust theoretical frameworks, such as the AMO theory (Hair et al., 2022).

Table 3: Fornell-Larcker Criterion

Construct	EKL	EP	GIP	GK	PP	SMI
Environmental Knowledge Learning (EKL)	**0.847**					
Environmental Performance (EP)	0.687	**0.879**				
Green Innovation Practice (GIP)	0.742	0.879	**0.893**			
Green Knowledge (GK)	0.693	0.595	0.565	**0.796**		
Peer Pressure (PP)	0.730	0.657	0.698	0.684	**0.810**	
Social Media Influence (SMI)	0.774	0.775	0.760	0.656	0.722	**0.823**

Table 4: Heterotrait-Monotrait (HTMT)

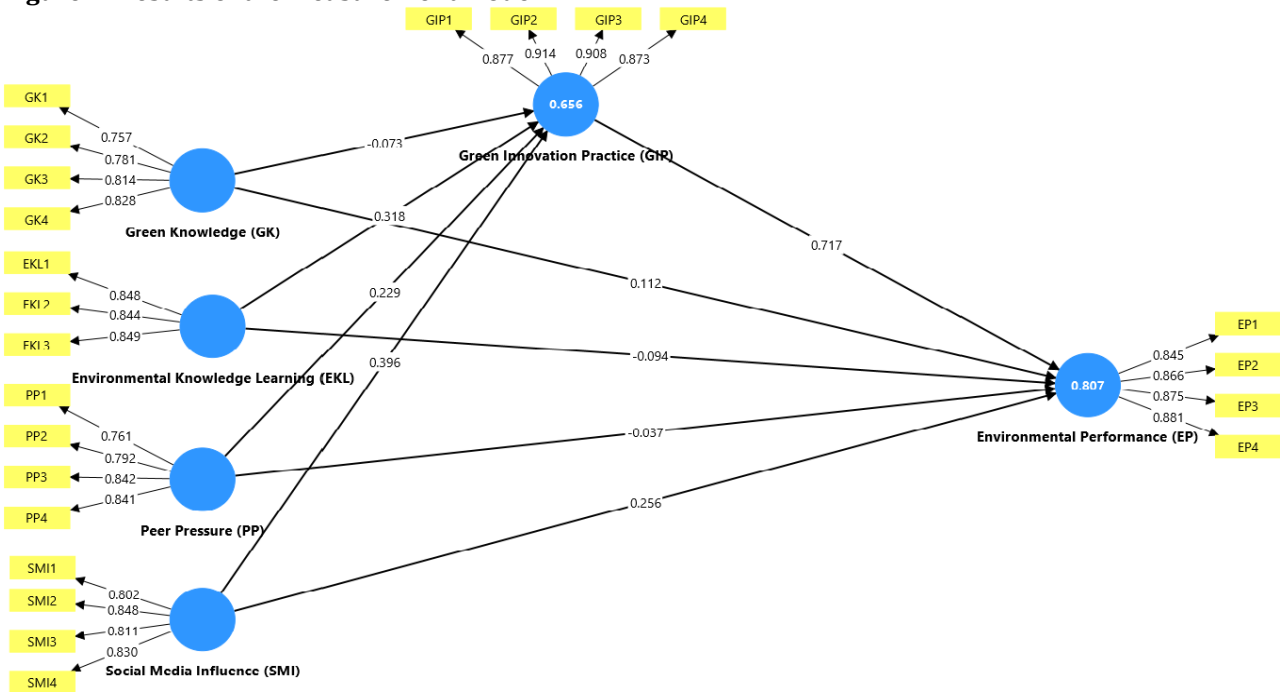
Construct	1	2	3	4	5	6
1. Environmental Knowledge Learning (EKL)	—					
2. Environmental Performance (EP)	0.810	—				
3. Green Innovation Practice (GIP)	0.865	**0.902**	—			
4. Green Knowledge (GK)	0.830	0.676	0.620	—		
5. Peer Pressure (PP)	0.891	0.754	0.793	0.804	—	
6. Social Media Influence (SMI)	**0.901**	0.895	0.867	0.775	0.855	—

Measurement Model Assessment

Figure 2 illustrates the outcomes of the measurement model assessment conducted via SmartPLS. This evaluation was performed to rigorously verify the reliability and validity of the six latent constructs employed in the study: Green Knowledge (GK), Environmental Knowledge Learning (EKL), Peer Pressure (PP), Social Media Influence (SMI), Green Innovation Practice (GIP), and Environmental Performance (EP). As depicted in the figure, the outer loadings for all measurement items significantly exceed the recommended threshold of 0.70 (Hair et al., 2022). Specifically, the indicator loadings range from a minimum of 0.757 (GK1) to a maximum of 0.914 (GIP2). These robust outer loadings confirm high indicator reliability, demonstrating that each item meaningfully captures a substantial portion of the variance in its respective latent construct. Because all items successfully met this criterion, no indicators required removal, and all were retained for subsequent analysis.

Furthermore, the strength of the outer model aligns perfectly with the study's broader assessments of internal consistency and convergent validity. The empirical findings confirm that all constructs achieved Composite Reliability (CR) scores well above the acceptable 0.70 benchmark, establishing strong internal consistency among the measurement items. Concurrently, the Average Variance Extracted (AVE) values for all constructs surpassed the critical 0.50 threshold. This indicates excellent convergent validity, verifying that each latent construct explains more than half of the variance of its corresponding indicators. In summary, the comprehensive evaluation of the measurement model provides compelling evidence that the research instrument is both highly reliable and valid. The constructs effectively and accurately measure the underlying phenomena linking Green Knowledge, Environmental Knowledge Learning, Peer Pressure, Social Media Influence, Green Innovation Practice, and Environmental Performance. Having firmly established the robust psychometric properties of the measurement model, the framework is deemed highly appropriate for proceeding to the structural model evaluation and subsequent hypothesis testing.

Figure 2: Results of the Measurement Model

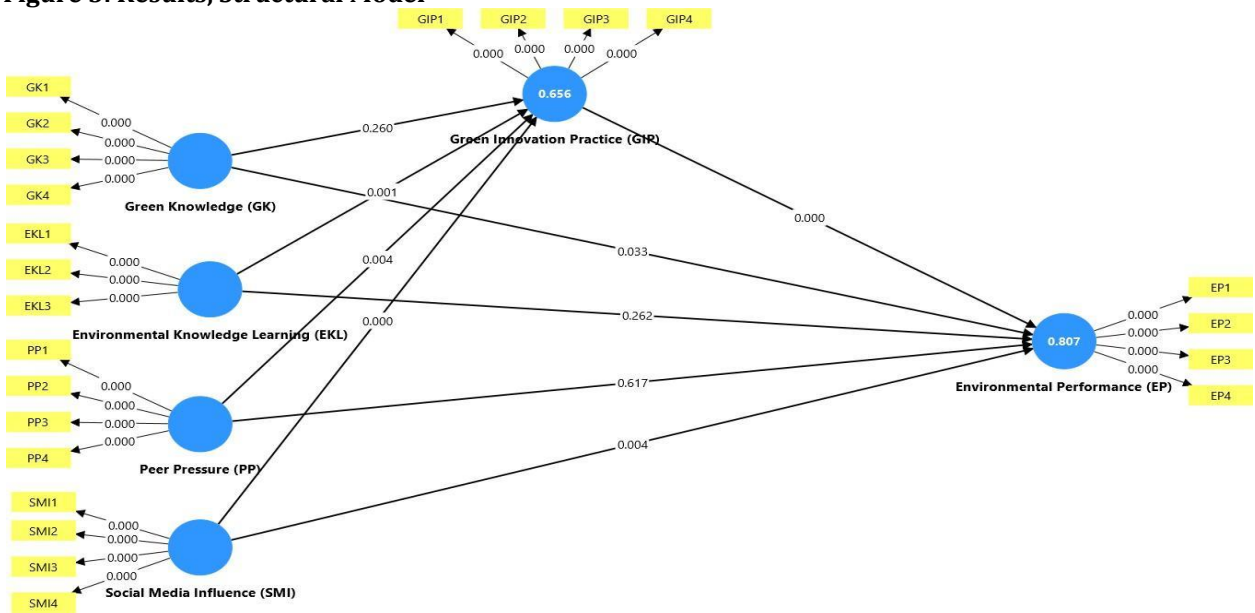


Structural Model Assessment

Prior to hypothesis testing, collinearity was assessed using the Variance Inflation Factor (VIF). All VIF values ranged between 2.282 and 3.469, which are well below the critical threshold of 5.0, confirming the absence of multicollinearity issues (Hair et al., 2022).

Explanatory Power (R^2) **and Effect Size** (f^2): The model demonstrated strong predictive accuracy. The R^2 value for Environmental Performance (EP) was 0.807, indicating that 80.7% of its variance is explained by the predictors. Similarly, the predictors explained 65.6% (R^2= 0.656) of the variance in Green Innovation Practice (GIP). Analysis of effect sizes (f^2) revealed that GIP has a large effect on EP (f^2 = 0.913), while Social Media Influence has a medium effect on GIP (f^2= 0.156).

Figure 3: Results, Structural Model



Hypothesis Testing (Direct Effects) Bootstrapping was employed to test the direct hypotheses. The results indicate that GK (β values= 0.112, p = 0.033) and SMI (β values= 0.256, p = 0.004) significantly and positively affect EP, supporting **H1** and **H4**. However, EKL (β values= -0.094, p = 0.262) and PP (β values = -0.037, p = 0.617) did not directly influence EP, leading to the rejection of **H2** and **H3**.

Regarding the antecedents of GIP, EKL (β = 0.318, p = 0.001), PP (β = 0.229, p = 0.004), and SMI (β = 0.396, p = 0.000) demonstrated significant positive effects, supporting **H6, H7**, and **H8**. GK did not significantly affect GIP, rejecting **H5**. Finally, GIP exerted a strong, significant positive effect on EP (β values = 0.717, p = 0.000), supporting **H9**.

Table 6: Hypothesis Testing (p-Value)

Hypothesis	Path Relationship	β (Original Sample)	t-value	p-value	Decision
H1	GK → EP	0.112	2.136	0.033	Supported
H2	EKL → EP	-0.094	1.123	0.262	Not Supported
H3	PP → EP	-0.037	0.500	0.617	Not Supported
H4	SMI → EP	0.256	2.885	0.004	Supported
H5	GK → GIP	-0.073	1.128	0.260	Not Supported
H6	EKL → GIP	0.318	3.459	0.001	Supported
H7	PP → GIP	0.229	2.892	0.004	Supported
H8	SMI → GIP	0.396	4.484	<0.001	Supported
H9	GIP → EP	0.717	5.942	<0.001	Supported

Mediation Analysis (Bootstrapping – Specific Indirect Effects) Mediation analysis was conducted to test the indirect effects of the predictors on EP via GIP.

The bootstrapping analysis examined the indirect effects of Peer Pressure (PP), Social Media Influence (SMI), and Environmental Knowledge Learning (EKL) on Environmental Performance (EP) through Green Innovation Practice (GIP). The results indicate that the mediating effect of GPI on the relationship between Green Knowledge GK and EP was not significant (β = -0.052, t = 1.129, p = 0.259). Therefore, no mediation effect was established. In contrast, SMI demonstrated a significant indirect effect through GIP towards EP (β = 0.164, t = 2.950, p = 0.003), indicating a full mediation effect. Additionally, EKL showed a significant indirect effect through GIP towards EP (β = 0.228, t = 3.179, p = 0.001), confirming a full mediation effect. The direct pathway involving GIP as a mediator between SMI and EP also showed a significant effect (β = 0.284, t = 3.998, p < 0.001), indicating partial mediation as shown in Table 7.

H10: GK → GIP → EP was insignificant (β = -0.052, p = 0.259), indicating no mediation. (Not Supported)
H11: EKL → GIP → EP was significant (β = 0.228, p = 0.001). Given the lack of a direct effect, this indicates *full mediation*. (Supported)
H12: PP → GIP → EP was significant (β = 0.164, p = 0.003). Similarly, this indicates *full mediation*. (Supported)
H13: SMI → GIP → EP was significant (β = 0.284, p = 0.000). Because the direct effect was also significant, this indicates *partial mediation*. (Supported)

Table 7: Mediation Results

Indirect Path	β	t-value	p-value	Result	Mediation Type
GK → GIP → EP	-0.052	1.129	0.259	Not Significant	No Mediation
EKL → GIP → EP	0.228	3.179	0.001	Significant	Full Mediation
PP → GIP → EP	0.164	2.950	0.003	Significant	Full Mediation
SMI → GIP → EP	0.284	3.998	0.000	Significant	Partial Mediation

Table 8 shows the summary of mediation analysis results which reveal how different factors drive EP through GIP. From the results, it indicates that GK shows No Mediation. GK has a direct, positive impact on Environmental Performance. However, it does not significantly influence the mediator (GIP). This suggests that individuals with high foundational green knowledge may directly engage in standard environmentally responsible behaviors without necessarily adopting green practices. Next, EKL and PP show Full Mediation.

Neither EKL nor PP directly improves Environmental Performance on their own. Instead, their impact is fully absorbed by the mediator. This means that EKL and PP act as motivational catalysts which it encourages young adults to adopt Green Innovation Practices, which in turn leads to better Environmental Performance. And SMI shows Partial Mediation. SMI is a powerful dual-driver of behavior. It directly enhances Environmental Performance while also indirectly boosting it by encouraging the adoption of Green Innovation Practices.

Table 8: Summary of Mediation Results

Independent Variable	Direct Effect (to EP)	Direct p-value	Indirect Effect (via GIP to EP)	Indirect p-value	Mediation Type
Green Knowledge (GK)	GK → EP	0.033 (Significant)	GK → GIP → EP	0.259 (Not Significant)	No Mediation
Environmental Knowledge Learning (EKL)	EKL → EP	0.262 (Not Significant)	EKL → GIP → EP	0.001 (Significant)	Full Mediation
Peer Pressure (PP)	PP → EP	0.617 (Not Significant)	PP → GIP → EP	0.003 (Significant)	Full Mediation
Social Media Influence (SMI)	SMI → EP	0.004 (Significant)	SMI → GIP → EP	0.000 (Significant)	Partial Mediation

Discussion

The empirical findings provide critical insights into how knowledge-based and social determinants drive Environmental Performance among young adults in the Klang Valley. A central finding is the profound role of Green Innovation Practice (GIP). The strong direct impact of GIP on EP aligns with previous studies (Wang et al., 2021; Hejazi et al., 2023; Bai & Lyu, 2023), confirming that behavioral implementation is crucial; awareness alone is insufficient without the translation of eco-friendly concepts into tangible daily practices. Interestingly, Environmental Knowledge Learning (EKL) and Peer Pressure (PP) did not directly affect Environmental Performance. However, they strongly influenced GIP, resulting in full mediation. This indicates that continuous environmental learning (Su et al., 2020) and peer validation (Rahnama Haratbar et al., 2023) primarily serve as motivational catalysts. They encourage young adults to adopt innovative green practices, which subsequently drive environmental performance.

Social Media Influence (SMI) emerged as a powerful dual driver, affecting Environmental Performance both directly and indirectly through GIP (partial mediation). This supports the assertions of Sun and Xing (2022), highlighting that digital platforms not only raise environmental awareness directly but also effectively mobilize young adults to experiment with and adopt sustainable lifestyle changes. Conversely, Green Knowledge (GK) exhibited a direct impact on EP but failed to significantly influence GIP. This suggests that individuals with high foundational green knowledge may execute standard environmentally responsible behaviors (such as basic recycling) directly without necessarily adopting novel "innovative" green practices. This finding aligns with Meng Zhang et al. (2024), who noted that fundamental knowledge directly predicts routine pro-environmental decision-making.

Overall, the findings validate the proposed conceptual framework. While knowledge and social influence are critical, their ultimate impact on environmental outcomes is largely dependent on their conversion into actionable Green Innovation Practices (Bai & Lyu, 2023; Hair et al., 2022).

5. Conclusion and Implications

This study successfully investigated the determinants of environmental performance among young adults, with a specific focus on the mediating role of green innovation practice. The findings indicate that while knowledge and social factors are important, they do not generally act as direct drivers of environmental outcomes. Specifically, Green Knowledge (GK) and Social Media Influence (SMI) have significant direct positive effects on Environmental Performance (EP). In contrast, the direct pathways from Environmental Knowledge Learning (EKL) and Peer Pressure (PP) to EP were found to be non-significant.

Instead, the most critical driver of environmental performance is the active engagement of individuals in green

innovation practices. Green Innovation Practice (GIP) was found to have the strongest direct effect on EP and serves as a vital behavioral bridge: it fully mediates the influence of EKL and PP, and partially mediates the effect of SMI. However, GIP does not mediate the relationship for foundational Green Knowledge. Ultimately, these results underscore that mere environmental awareness or social pressure is often insufficient on its own; it must be translated into tangible, action-oriented behaviors to achieve meaningful environmental outcomes (Singh et al., 2020; Javed et al., 2026)

Theoretical Implications

This research offers significant contributions to existing theoretical frameworks. Primarily, it provides empirical validation for applying the Ability–Motivation–Opportunity (AMO) Theory to elucidate environmental performance among young adults (Bos-Nehles et al., 2013). Within this context, knowledge-related variables represent ability, social influences denote motivation, and Green Innovation Practice embodies the opportunity and behavioral application required to form performance outcomes. Furthermore, this study enhances current literature by affirming that Green Innovation Practice serves as a pivotal behavioral mechanism (Wang, 2019). While prior research frequently emphasized the importance of knowledge and awareness (Farrukh et al., 2022), these findings support modern theories suggesting that behavioral engagement is an essential link between cognition and actual performance. Finally, by explicitly identifying the non-significant direct relationships (EKL and PP to EP) and contrasting them with significant direct and indirect effects, this study clarifies the divergent roles that cognitive and social factors play in influencing environmental outcomes.

Practical Implications

The results of this study offer actionable insights for educational institutions, policymakers, and environmental organizations. First, educational institutions should shift their environmental curricula from theoretical instruction to practical application (Luo et al., 2022; Afsar et al., 2018; Afsar et al., 2020; Gilal et al., 2019). Implementing project-based learning, green innovation contests, and hands-on sustainability programs will allow students to practice being environmentally responsible, thereby improving overall environmental performance. Second, policymakers and government agencies should design action-oriented environmental programs. Because Green Innovation Practice is highly influential, policies should explicitly encourage youth involvement in green entrepreneurship, community environmental projects, and sustainable lifestyle campaigns (Mehrajunnisa et al., 2022). Third, organizations and NGOs should strategically leverage social media platforms. By creating engaging digital campaigns, organizations can simultaneously raise awareness and directly encourage young adults to alter their behaviors (Nilashi et al., 2022; Jabbour et al., 2011; Jackson et al., 2011; Jackson et al., 2014). Finally, environmental initiatives should incorporate peer-based interventions. Since peer pressure affects behavior solely through indirect pathways via Green Innovation Practice (Huang et al., 2026; Muysioa et al., 2022; Okoye & Eze, 2023), initiatives such as group challenges, peer-led sustainability clubs, and collaborative green activities can significantly enhance practical engagement and effectiveness.

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Mapping the Global Trends and Thematic Evolution of Big Data Analytics Capabilities Research: A Bibliometric Review

*Nur Zania Azurin Abdullah Sani[1,2], Noor Ismawati Jaafar[1], Farzana Parveen Tajudeen[1]
[1]Department of Decision Science, Faculty of Business and Economics, Universiti Malaya, Kuala Lumpur, Malaysia
[2]Department of International Business and Business Management Studies, Faculty of Business & Management, Universiti Teknologi MARA, Selangor, Malaysia
Email: *nurzan7884@uitm.edu.my
Corresponding Author: Nur Zania Azurin Abdullah Sani

Abstract: The objective of the paper is to explore and analyze global research trends, influential works, and key themes in Big Data Analytics Capabilities (BDAC) and to identify the most active authors, institutions, countries, and journals contributing to the field. Adopting bibliometric tools such as Bibliomagika, OpenRefine, VOSviewer, and Biblioshiny, this study used a bibliometric approach to collect 281 journal articles, conference papers, book chapters, reviews, and other document types from the Scopus database. By cleansing the data beforehand, this ensures the accuracy and reliability of subsequent analyses, enabling researchers to derive meaningful insights with confidence. The results clearly show a steady growth in BDAC-related publications over the past five years (2020–2024). This trajectory reflects the increasing scholarly interest and recognition of BDAC as a crucial organizational capability, especially in the context of digital transformation and firm performance. The findings revealed thematic cluster analyses that uncovered five dominant research themes. Firm performance and decision-making, sustainability and green supply chains and green innovation, business model innovation, artificial intelligence integration, and healthcare and sectoral applications.

Keywords: *Bibliometric analysis, big data analytics, big data analytics capabilities, data-driven culture*

1. Introduction

Big Data Analytics Capabilities (BDAC) have emerged as a key component of contemporary organizational strategy and competitiveness in an era characterized by exponential data growth. Organizations across all sectors are being compelled to utilize substantial volumes of both structured and unstructured data to facilitate informed decision-making, enhance operational effectiveness and foster innovation (Mikalef et al., 2018).

The ability of a company to obtain, handle, evaluate, and apply big data assets to create business value is known as BDAC. This ability encompasses organizational culture, technical infrastructure, trained staff, and strategic alignment, making it a complex concept with increasing significance. Over the past decade, scholarly interest in BDAC has increased as it has gained popularity in industries such as business, healthcare, and manufacturing.

The body of knowledge in BDAC literature remains widely spread, despite its focus on specific industries. Without providing a thorough overview of the field's conceptual evolution, existing research frequently focuses on particular elements, such as technology platforms, human expertise, or domain-specific applications. Furthermore, studies on BDAC are scattered throughout numerous journals and fields, making it challenging to identify significant contributions, trends in collaboration, and new themes. A thorough bibliometric analysis is required to fill these gaps by methodically mapping the field of BDAC research and providing more precise insights into its intellectual framework and future directions. The objective of the paper is to explore and analyze global research trends, influential works, and key themes in Big Data Analytics Capabilities (BDAC). Other than that, to identify the most active authors, institutions, countries, and journals contributing to the field. This study aims to answer the following research questions.

- What are the trends in publication for BDAC research?
- Who are the most prominent authors, and what themes dominate their work?
- What are the most influential institutions and countries in BDAC research?
- Which are the most active journals in publishing BDAC-related studies?
- What are the most highly cited documents and the themes they explored in BDAC?

- What are the most common keywords, and how have they evolved?
- What key themes emerge from co-occurrence analyses of keywords and title/abstract terms?

The rest of this paper is structured as follows. The next section presents a literature review that charts the historical and recent development of BDAC research, emphasizing theoretical frameworks and prior bibliometric efforts. Section 3 describes the methodological approach for data collection, processing, and analysis. Section 4 provides pieces of evidence of the results of the bibliometric analysis, including descriptive insights and thematic mappings. Lastly, Section 5 offers a discussion of findings and implications, while Section 6 concludes with key takeaways, research limitations, and directions for future exploration.

2. Literature Review

The roots of Big Data Analytics Capability (BDAC) lie at the intersection of data technology and strategic management theory. This reflects how BDAC emerged as a link between technological advancements in big data infrastructure and analytics and strategic value creation in organizations. In a previous study by Yong et al. (2019), their focus was directed toward big data infrastructure and storage systems. The promise of adopting a big data strategic architecture is that it maximizes technologies' capabilities in automating decision-making and drives these values through innovation. Over time, however, focus shifted toward the strategic use of data and analytics as a capability that drives organizational value. The early ideas, such as those by Barney (1991), drew upon the Resource-Based View (RBV), positioning BDAC as a valuable, rare and inimitable resource, whereas early on BDAC scholars like Mikalef et al. (2018) have emphasized that it requires specific capabilities beyond regular ones to develop big data-specific capabilities. Building on this, Dynamic Capabilities Theory (Teece, 2007) has been used to explain how firms continuously develop, integrate, and reconfigure analytics capabilities in response to environmental changes.

Over the past decade, scholarly interest in BDAC has increased as it has gained popularity in industries such as business, healthcare, and manufacturing. But recent studies have shown that BDAC has permeated a wide range of sectors, from finance and healthcare to sustainability. Recent studies explored BDAC's role in applying sustainability practices such as green supply chain sustainability (Rahman et al., 2024). The statistical analysis revealed that BDAC positively impacts all three dimensions of supply chain sustainability: economic, social, and environmental. Additionally, green supply chain management (GSCM) practices significantly moderate the relationship between BDAC and supply chain sustainability (Rahman et al., 2024). While others explored BDAC's influence on sustainable business performance (Novicka and Volkova, 2025). Their study contributes the BDAC elements' key success factors necessary to integrate sustainability reporting into organizational processes. Other than that, there are studies focused on the application of BDAC to financial reporting quality (Aboelfotoh et al., 2025) and the adoption of big data analytics in financial auditing (Maulani & Widuri, 2024), and Thayyib et al. (2023) analyzed its integration with artificial intelligence across multiple domains. Overall, these studies show a shift of BDAC from a support function to a strategic driver. There are also studies on bibliometric analysis conducted on healthcare sectors, as big data analytics has become an effective tool in the healthcare industry, revolutionizing medical research, patient care, and healthcare management (Mohd Daril et al., 2024).

On the methodological front, bibliometric tools such as VOSviewer and Biblioshiny have enabled researchers to conduct deeper and more nuanced analyses (Pathak et al., 2024; Aboelmaged & Mouakket, 2020). Co-citation networks, keyword trends, and thematic mapping have proven particularly effective in uncovering latent patterns within the literature (Thayyib et al., 2023). Recent studies have also begun to integrate advanced techniques such as mixed methods and topic modeling (Fauzi et al., 2023). Theoretically, scholars are expanding the scope of BDAC inquiry by incorporating stakeholder theory, Environmental, Social and Governance (ESG) frameworks, and digital transformation paradigms (Murad et al., 2023; Novicka & Volkova, 2025; Dubey et al., 2019). Organizations are not only harnessing and analyzing big data for improved transparency and decision-making but also for improving collaboration among partners in supply chains to meet sustainability goals and address environmental issues (Dubey et al., 2019).

Several scholars have attempted to chart the BDAC research landscape using bibliometric techniques. Inamdar et al. (2021) conducted a review focusing on big data analytics (BDA) adoption between 2014 and 2018, with

an emphasis on enabling technologies and implementation challenges. The author has found that the benefits of adopting BDA, coupled with a lack of adequate research in the field, have motivated their study. The bibliometric analysis they conducted has categorized papers into seven main areas and found that most of the studies were carried out in manufacturing and services.

Other bibliometric analyses conducted by Aboelmaged and Mouakket (2020) examined key influencing models and determinants in big data analytics, which suggest that the analysis reveals that BDA adoption research demonstrates attributes suggestive of a topic at an initial stage of development as it is broadly dispersed across different domains and employs a wide range of models, some of which overlap. Most of the applied models are generic in nature, focusing on variance-based relationships and snapshot prediction with little consensus. Fauzi et al. (2023) looked at how BDA intersects with human resource management. The bibliometric study conducted on the human resource area has found significant research clusters that imply the knowledge structure and mapping of research streams in HRM.

More recently, Pathak et al. (2024) delivered a sophisticated bibliometric and co-citation analysis, identifying core research clusters such as capability antecedents, business value creation, and organizational adaptability. In sum, most of the current research focuses on the value creation mechanisms of BDAC but uses multiple theoretical logics to examine it. The evolving research themes indicate an emphasis on supply chain (resilience, agility, sustainability), manufacturing performance, innovation, competitive performance, and strategic value creation.

Other contributions by academicians and practitioners have recently begun to accord artificial intelligence (AI) and big data analytics (BDA) significant consideration when exploring emerging research trends in different fields. Thayyib et al. (2023) provided a cross-domain bibliometric summary of BDA and artificial intelligence across five key industries, highlighting the growing interdisciplinary nature of the field. While all these studies have expanded the field's analytical scope, many have not delved deeply into performance-related constructs or the evolving theoretical paradigms underpinning BDAC.

However, while other authors are focusing on conducting reviews on how big data analytics intersects with other disciplines and technology adoption, Rialti et al. (2019) have focused directly on the capability view of big data analytics. The author conducted a bibliometric analysis that revealed four clusters of papers on big data and dynamic capabilities. The four clusters were classified as big data and supply chain management, knowledge management, decision-making, business process management, and big data analytics. At the same time, the author conducted a systematic literature review, which helped to clarify each cluster's content. Building on this foundation, the current study offers a focused and updated bibliometric review exclusively targeting BDAC literature. By analyzing a cleaned Scopus dataset, it contributes refined insights into the intellectual architecture, thematic directions, and collaborative networks shaping the field.

3. Method

This study employed a bibliometric approach using a final corpus of 281 Scopus-indexed journal articles, conference papers, book chapters, reviews, and other document types from the Scopus database. The well-known database Scopus served as the basis for this study's data collection for the bibliometric analysis. Using the Scopus database allows researchers to discover curated research and enrich data and scholarly literature to support academic research with comprehensive content. It also offers global coverage, enabling researchers to access critical, high-quality research from developing countries. The study uses the search field by extracting articles based on the article title, abstract, and keywords.

Data were retrieved from the Scopus database on 25 November 2024. Scopus was selected because of its broad multidisciplinary coverage and structured bibliographic metadata, which are suitable for bibliometric analysis. The search was performed using the title, abstract, and keyword fields with the query TITLE-ABS-KEY ("big data analytics capabilities"), limited to publications between 2020 and 2024. The initial search returned 354 records. To improve conceptual precision, the retrieved records were manually screened by reviewing their titles and abstracts. Records were excluded when the search term did not refer to Big Data Analytics Capability, when BDAC was mentioned only incidentally without substantive relevance to the study, or when the record

did not provide sufficient bibliographic information for analysis.

Following screening, 73 records were excluded and 281 documents were retained for bibliometric analysis. The final dataset included different Scopus-indexed publication formats to capture the broader scholarly development of BDAC research. Bibliographic information extracted included publication title, year, author names and affiliations, source title, abstract, author keywords, and citation counts. The keyword search looks at general terms of "big data analytic capabilities." With the specific keyword, this study aims to investigate the evolution of the specific construct Big Data Analytics Capabilities (BDAC) as conceptualized in the resource-based view and dynamic capability literature. This methodological rationale acknowledges that the use of a construct-specific search string may have excluded studies employing alternative terminology, which is now stated as a limitation and an avenue for future research.

Additionally, only publications from the years 2020 to 2024 were chosen for the analysis. The following information was combined with the data from the bibliometric search. (i) the title of the paper, (ii) the date of publication, (iii) the main author details (name(s) and affiliation(s)), (iv) the title of the article, (v) the authors' keywords, (vi) the abstract, and (vii) the number of citations. The data were analyzed and presented using the new bibliometric tool BiblioMagika (Ahmi, A., 2024) along with other introduced tools like VOSviewer and RStudio's Biblioshiny packages (Ragazou et al., 2023). These tools provided analysis tables, graphs, and maps, such as network visualization maps that demonstrate the research trends. BiblioMagika is an Excel-based tool designed for conducting bibliometric analysis, with a focus on assessing publication productivity and evaluating scholarly impact. It offers a range of calculations, including total publications (TP), contributing authors (NCA), cited publications (NCP), total citations (TC), average citations per publication (C/P), average citations per cited publication (C/CP), h-index, g-index, m-index, citations sum within the h-core, cumulative total publications, and more. This analysis can be performed across various parameters such as publication year, source titles, authors, affiliations, and countries.

BiblioMagika streamlines the data cleaning and harmonization process for author names and affiliations, ensuring standardized data presentation for accurate analyses (Ahmi, 2024). Additionally, it facilitates the identification of missing data and offers tools for data completion. Moreover, BiblioMagika prepares datasets for compatibility with other bibliometric tools such as VOSviewer and Biblioshiny. By cleansing the data beforehand, it ensures the accuracy and reliability of subsequent analyses, enabling researchers to derive meaningful insights with confidence. Data collected from Scopus for this study, referring to Figure 1, includes the keyword search is shown and thoroughly stated in the PRISMA diagram. The bibliographic data were retrieved from Scopus in November 2024.

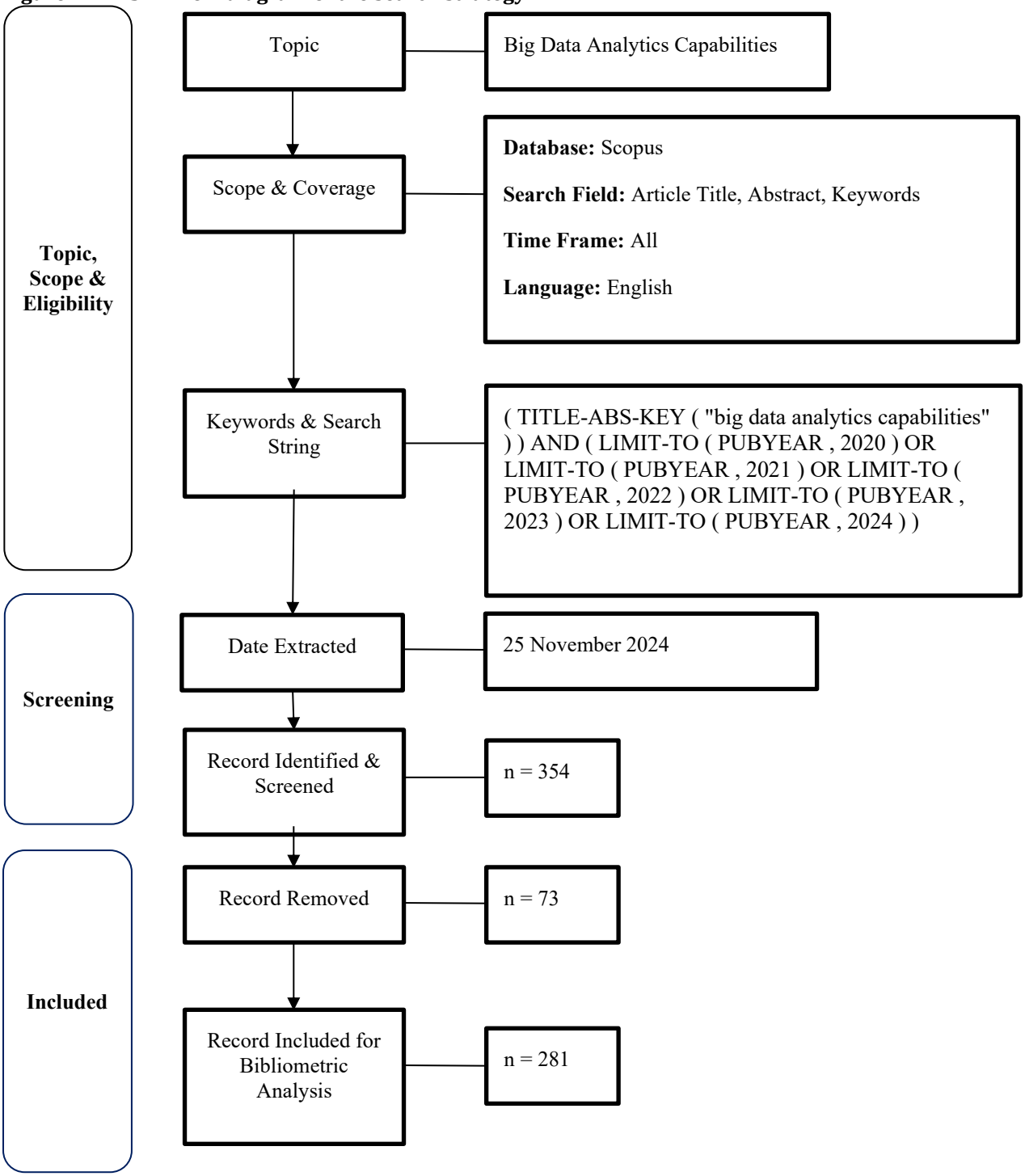
Data cleaning and consistency verification were conducted before the bibliometric analysis. This process is to improve the reliability and accuracy of the dataset. Bibliometric datasets exported from Scopus frequently contain inconsistencies arising from variations in authors' names, institutional affiliations, keywords and document metadata. These inconsistencies may distort publication counts, collaboration networks, citation analysis, and keyword co-occurrence maps.

The initial dataset of 354 records was first screened manually by reviewing the titles and abstracts to ensure conceptual relevance to big data analytics capability (BDAC). Those documents that were not related to the study objectives, duplicate records and publications outside the predefined inclusion criteria were removed, resulting in the final dataset of 281 publications. Later, the bibliographic records were cleaned using BiblioMagika®, followed by verification in Biblioshiny (Bibliometrix) before being imported into VOSviewer for network visualization.

The data cleaning process included removal of duplicate records; standardization of author names where alternative spellings or name variants existed; harmonization of institutional affiliations to combine identical institutions recorded under different names; verification of publication years, document types, and source titles; correction of inconsistencies in author keywords by merging synonymous terms and resolving spelling variations where appropriate; and validation of missing or incomplete bibliographic metadata where possible. Following data cleaning, the dataset was subjected to consistency checks by comparing publication counts across document types, source types, publication years, countries, authors, and journals. The totals reported in

all descriptive analyses were cross-validated to ensure consistency throughout the study. This process minimized potential bias caused by duplicate records, inconsistent metadata, and fragmented author or institutional identities, thereby improving the robustness and reproducibility of the bibliometric findings.

Figure 1: PRISMA flow diagram of the search strategy.



4. Results

Table 1 shows that the 281 documents in the dataset have been categorized based on the publication type, sources, languages, and subject area.

According to Table 1, showing the dominance of journal articles dominate. The articles accounted for 78.29% (220 publications), which indicates that most of the research output on the topic of big data analytics capabilities (BDAC) and firm performance has been published in peer-reviewed academic journals. This high percentage shows a high level of academic interest and possibly rigorous peer-review standards contributing to the development in this field. The next most common document types are conference papers (12.81%) and book chapters (4.27%). Conference papers are the type of documents that have been published in Scopus, showing ongoing discussions and presentations at academic gatherings, which often precede journal publication, and this also indicates emerging research directions on the particular topic. Book chapters suggest a specific topic or theme, such as big data analytics capabilities. The others have been categorized as review papers, errata, and retracted papers. Review papers (2.14%) are relatively limited, suggesting a gap in comprehensive summaries or syntheses in this field, which highlights an opportunity for future research. Erratum and retracted documents, constituting only 0.36%, each, show high data integrity and minimal issues in Scopus. Therefore, it is proven that the topic BDAC is primarily journal-driven, which is considered to have good impact and citation visibility. The results have shown a relatively small number of review articles, which can become an opportunity for researchers to embark on writing big data analytics capability review articles, which will fill a needed gap.

Table 1: Document Type

Document Type	Total Publications (TP)	Percentage (%)
Article	220	78.29
Conference Paper	36	12.81
Book Chapter	12	4.27
Review	6	2.14
Conference Review	5	1.78
Erratum	1	0.36
Retracted	1	0.36
Total	281	100

Referring to Table 2, the table illustrates the distribution of publication sources from which BDAC and firm performance-related studies emerged. Journal source type is shown to dominate the field, where journals contributed 81.49% (229 publications) of the total sources. This information is consistent with Table 1, which confirms that the most contributions to the field are peer-reviewed and academically validated. Journal publications also indicate that the area is gaining researchers' interest, scholarly maturity, and recognition. Conference proceedings (11.03%) represent a smaller but significant share of the contribution. Usually, a conference is a stepping stone for early-stage and emerging researchers to showcase their new ideas as well as gather peer or expert feedback before finalizing the journal publication. The remaining data sources came from book series (5.34%) and books (2.14%), which include common themes of BDAC, suggesting a growing interest in the field, especially in the fields of strategic orientation, dynamic capabilities, value creation, and capabilities. The study uses the dynamic capability approach to investigate how turbulent and competitive contexts influence big data analytics capabilities, which in turn affect supply chain (SC) agility (Cadden et al., 2021). The study by Park et al. (2021) seeks to evaluate the impact of big data analytics capacity on big data values and business performance in organizations that undertake big data analytics, which is one of the leading technologies in the fourth industrial revolution. Big data values in this study include transactional, strategic, transformative, and informative. Whereas Moseneke and Brown (2022) stated that their study focuses on describing BDAC requirements to build business value that originates from the work practice level, this topic is regarded as less investigated. All these are presented in the form of books and book series, which show interdisciplinary and long-form engagement with the topic, which may offer more conceptual or case-based perspectives.

Table 2: Source Type

Source Type	Total Publication (TP)	Percentage (%)
Journal	229	81.49
Conference Proceeding	31	11.03
Book Series	15	5.34
Book	6	2.14
Total	281	100

Table 3 highlights the language distribution of the 281 publications in the dataset. English has been identified as the dominant language, as 100% of the documents are published in English, although one also includes Chinese (0.36%) and Serbian (0.36%), which are most likely dual-language publications. This confirms that BDAC and firm performance research are globally oriented and are sought broadly by scholarly reach through the use of the lingua franca of academia, which is English. For global accessibility and citation potential, an English-language publication is preferred in this area. Regional viewpoints may be under-represented, especially in non-English-speaking developing economies where BDAC adoption is increasing. Future studies could look into grey literature or local databases to collect these regional insights if inclusivity or context-specific analysis is required.

Table 3: Languages

Language	Total Publications (TP)	Percentage (%)
English	281	100.00%
Chinese	1	0.36%
Serbian	1	0.36%
Total	281	100

*One or two documents have been prepared in dual languages

Table 4 categorizes publications based on their subject classifications. Most papers are indexed in more than one area, reflecting the multidisciplinary nature of BDAC. The top dominant fields are business, management, and accounting (60.14%). Expectedly, this shows that BDAC is most often applied in the context of organizational performance, strategic decision-making, and resource utilization. In terms of firm performance, the study focuses on examining how BDAC influences firm performance through dynamic capabilities (Mikalef et al., 2020), sustainable performance in healthcare (Shokouhyar et al., 2020), data governance as a critical enabler of BDAC success, which is directly connected to firm performance and governance mechanisms (Mikalef et al., 2020), sustainability practices in manufacturing contexts (Bag et al., 2021), and supply chain sustainability and operational performance (Razaghi & Shokouhyar, 2021). These authors are key contributors to this area. Preceding the business management and accounting field is computer science (39.15%). As a technology-driven capability, BDAC's foundation in computing, for instance, data processing, artificial intelligence, and machine learning, reflects the collaboration between technical and business management disciplines. Decision sciences (24.91%) is marked as the 3rd dominant field. This is a key area where BDAC contributed to analytics for informed decisions in multiple areas like supply chain, finance, marketing, and strategic planning. Other supporting disciplines are social sciences (21%) and engineering (20.28%). This considers broader societal and systems-oriented applications, for instance, in smart cities, engineering processes, and analysis using human skills. There are also supporting disciplines such as environmental science (9.96%) and economics, econometrics, and finance (7.47%) that have emerged. This reflects the growing interest in using BDAC in sustainability, ESG performance, and economic analysis that certain studies uniquely target. In relation to BDAC, there are niche subject areas with emerging interest, such as psychology (6.05%), energy (5.69%), mathematics (4.98%), and medicine (1.07%). Here, the application of BDAC is assumed to understand human behavior, enhance predictive models in certain areas, and optimize the usage of energy. Concerning BDAC, this analysis highlights how intersections between business, technology, and environmental disciplines are evolving, and this might give insight for future research to focus on the subject areas that have less investigation, such as arts and humanities, medicine, materials science, physics and astronomy, chemical engineering, earth and planetary sciences, and nursing.

Table 4: Subject Area

Subject Area	Total Publications (TP)	Percentage (%)
Business, Management and Accounting	169	60.14
Computer Science	110	39.15
Decision Sciences	70	24.91
Social Sciences	59	21.00
Engineering	57	20.28
Environmental Science	28	9.96
Economics, Econometrics & Finance	21	7.47
Psychology	17	6.05
Energy	16	5.69
Mathematics	14	4.98
Arts and Humanities	5	1.78
Medicine	3	1.07
Materials Science	2	0.71
Physics and Astronomy	2	0.71
Chemical Engineering	1	0.36
Earth and Planetary Sciences	1	0.36
Nursing	1	0.36

Table 5 represents the publication year, including the annual distribution and citation performance related to significant big data analytics capabilities (BDAC). It also portrays the BDAC impact on firm performance over the last five years (2020-2024), based on the 281 documents in the dataset. Based on the output, the total number of publications (TP) has steadily increased from 30 (2020) to 94 (2024), showing that there's significant growth in academic interest in BDAC and its relationship with organizational and sustainability performance. This is consistent with the data observed in the dataset. By the year 2024, it was shown that 94 out of 281 total outputs accounted for 33%, showing that the field is still expanding rapidly. Referring to citation impact, there has been a decline in citation performance over time (2020-2024). Even though the publication output is rising, citation impact is declining. As seen in the table, average citations per publication (C/P) and citations per cited publication (C/CP) declined from 93.3 (2020) to just 4.57 (2024) and from 97.17 (2020) to 7.54 (2024), respectively. The declination is considered normal in bibliometric studies, as the older papers have had more time to accumulate citations. Usually, a high citation rate reflects early foundational studies; for instance, as referred to in this data, prominent authors in BDAC areas are Mikalef et al. and Wamba et al. in the years 2020-2021. The citation metrics, such as a reference to the h-index and g-index, offer insight into the productivity and impact of publications by year. The highest h-index (26) and g-index (38) are from the year 2022, which shows that there is a strong influence of papers from that year. Despite having more publications, 2023 and 2024 have lower h-/g-index values (16/22 and 12/18, respectively), indicating that they are newer and have not yet received considerable citations. Figure 2 reflects the same information in a chart format; the total publications and citations by year visualize both publication volume and citation impact over time. This dual-axis chart shows the blue bars and orange line, which constitute the total number of publications on the left Y-axis and the total number of citations on the right Y-axis. Overall, the 2 diagrams show that there is consistent growth in publication output (2020-2024), and this confirms that BDAC and the firm performance research field are growing steadily, especially in 2022-2024. In terms of citations, it can be seen that there is a declining citation trend despite growth. The total citations peak in 2020 (2818) and decline steadily to 2024 (430).

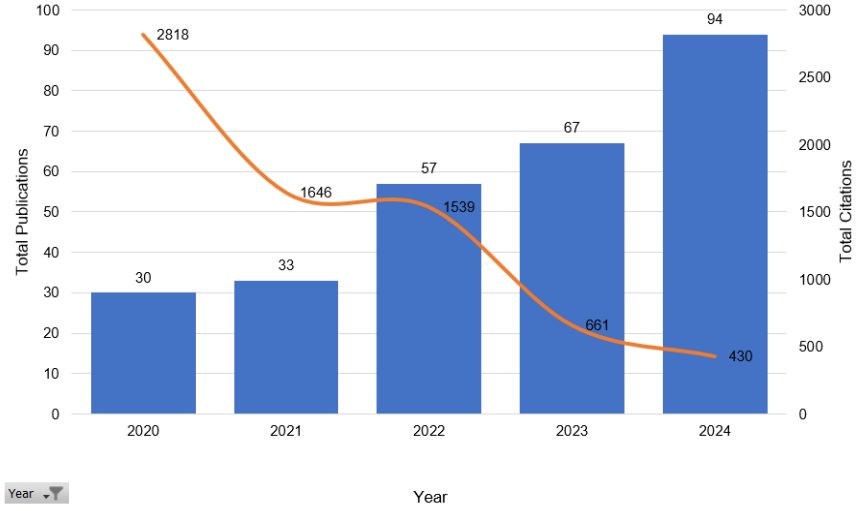
Table 5: Year of Publication

Year	TP	NCP	TC	C/P	C/CP	h-index	g-index
2020	30	29	2818	93.93	97.17	20	30
2021	33	30	1646	49.88	54.87	18	33
2022	57	48	1539	27.00	32.06	26	38

2023	67	52	661	9.87	12.71	16	22
2024	94	57	430	4.57	7.54	12	18
Grand Total	**281**	**216**	**7094**	**25.25**	**32.84**	**92**	**141**

Notes: TP=total number of publications; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; and g=g-index.

Figure 2: Total Publications and Citations by Year



Source: Generated by the author(s) using biblioMagika® (Ahmi, 2024)

Table 6 shows the most productive countries by total publications contributing to publications. This table presents the geographical distribution of BDAC publications from the dataset, highlighting key productivity and impact metrics by country. According to the table, the 5 most productive countries by total publications are 1) China (198 papers), 2) Malaysia (83 papers), 3) United Kingdom (73 papers), 4) Pakistan (39 papers), and 5) Italy (35 papers). China dominates publication productivity with 198 papers (27.77% of the total 713), more than other countries. Malaysia ranks notably high (83 papers), showing significant research involvement in this area within the region. According to the same table, the total citations (TC) impact is led by China, followed by the UK, Italy, the US, and Turkey. Despite China's (4423) lead in quantity, the United Kingdom (4174) is highly competitive in citation impact. The citation efficiency (C/P) shows the average citations per publication. The top-performing countries that have high average citations per paper are the US, the UK, Italy, and Finland. This indicates a focus on impactful and high-quality publications. Research productivity and impact indicators can be seen in the table in the columns h-index and g-index. China ranks the highest in h-index (37) and g-index (66), reflecting the country's productivity and influence contributed to publications. The UK follows with an h-index of 29 and a g-index of 64, which shows high-quality and impactful research output. Whereas the h-index (16) is comparable to developed countries like Turkey & Pakistan, it is believed that these countries are showing growing interest in research maturity. Additionally, countries like New Zealand, Finland, and Iran show outstanding citation efficiency, but they contribute only a few publications. Malaysia is the only ASEAN country that is listed in the top ranks, which shows a strong research footprint in BDAC topics. Other countries portraying low C/P and T/C might be emerging players or focused on local or applied research contexts. Conclusively, China is the leading player in most publications as the leading quantity producer in BDAC research. The countries that have the most citations is China.

The geographical distribution of BDAC studies has suggested that the field is becoming less concentrated within traditionally dominant Western research systems. Earlier reviews reported that BDAC studies were disproportionately situated in developed-country contexts (Murad et al., 2023). In contrast, referring to the results in Table 6. Most Productive Countries, the present analysis identifies China and Malaysia as the two most productive countries, followed by the United Kingdom. This pattern shows the increasing contribution of Asian research communities to the development of BDAC scholarship.

Table 6: Most Productive Countries

Country	TP	NCA	NCP	TC	C/P	C/CP	*h*	*g*	*m*
China	198	11	156	4423	22.34	28.35	37	66	6.167
Malaysia	83	11	64	967	11.65	15.11	16	31	3.200
United Kingdom	73	9	65	4174	57.18	64.22	29	64	4.833
Jordan	41	16	15	291	7.10	19.40	8	17	2.000
Pakistan	39	2	35	661	16.95	18.89	16	25	3.200
Italy	35	6	30	1794	51.26	59.80	12	35	2.400
Australia	32	10	25	602	18.81	24.08	10	24	1.667
Turkey	30	7	24	1270	42.33	52.92	11	30	1.833
United States	29	24	23	1551	53.48	67.43	15	29	2.500
United Arab Emirates	28	NR	23	476	17.00	20.70	10	21	2.000
Spain	19	2	12	228	12.00	19.00	5	15	1.000
Saudi Arabia	15	5	13	172	11.47	13.23	6	13	1.000
Iran	12	NR	12	428	35.67	35.67	7	12	1.167
Thailand	10	NR	9	102	10.20	11.33	8	10	1.333
Taiwan	10	2	6	247	24.70	41.17	5	10	0.833
Finland	6	NR	6	330	55.00	55.00	4	6	0.800
Ireland	6	NR	6	172	28.67	28.67	5	6	0.833
Canada	6	NR	6	129	21.50	21.50	5	6	1.250
Sweden	5	NR	4	171	34.20	42.75	3	5	0.500
Iraq	5	NR	1	5	1.00	5.00	1	2	0.333
Ghana	5	NR	5	112	22.40	22.40	2	5	0.500
Indonesia	5	51	5	5	1.00	1.00	1	2	0.333
Russian Federation	4	2	4	4	1.00	1.00	1	2	0.333
Portugal	3	2	3	6	2.00	2.00	2	2	0.667
South Korea	3	4	3	37	12.33	12.33	2	3	0.333

Note: TP=total number of publications; NCA=number of contributing authors; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; g=g-index, m=m-index.
Source: Generated by the author(s) using biblioMagika® (Ahmi, 2024)

Table 7 represents the institutional-level analysis highlighting the most productive institutions' productivity and citation impact for institutions contributing to BDAC research. The most productive institutions by the total number of publications (TP) are Jiangsu University (24), followed by the University of Technology Sydney (16), Harbin Institute of China Technology (15), Northwestern Polytechnical University (14), Universiti Sains Malaysia (11), and Universiti Kebangsaan Malaysia (9), and several institutions have minimally contributed to publication in the BDAC topic. This reflects that China has dominated the research area in terms of the number of publications. According to total citations (TC), the Norwegian University of Science and Technology (1932) stands out as the most influential institution, followed by the University of Florence (1061), Liverpool John Moores University (848), Harbin Institute of Technology (670), the University of Roehampton (652), and Jiangsu University (499). Referring to the most productive institution that has high research impact, Jiangsu University leads in both based on the h-index (14) and g-index (22). Conclusively, the field is highly influenced by China, Australia, and Malaysia.

Referring to Table 7, the results in the Most Productive Institutions indicate that China's domination is also visible at the institutional level as compared to Table 6 results, with Jiangsu University, Harbin Institute of

Technology, and Northwestern Polytechnical University among the leading contributors. Universiti Sains Malaysia and Universiti Kebangsaan Malaysia similarly support Malaysia's position. The United Kingdom, however, demonstrated a different pattern of influence, while its publication volume is lower than China's. Its citation per publication (C/CP) is considerably stronger: 106 and 33.27 (C/CP: China). This suggests that productivity and scholarly impact are not necessarily concentrated in the same national systems.

Table 7: Most Productive Institutions

Institution Name	Country	TP	NCP	TC	C/P	C/CP	*h*	*g*	*m*
Jiangsu University	China	24	15	499	20.79	33.27	14	22	3.500
University of Technology Sydney	Australia	16	13	182	11.38	14.00	5	13	0.833
Harbin Institute of Technology	China	15	15	670	44.67	44.67	12	15	2.000
Northwestern Polytechnical University	China	14	14	244	17.43	17.43	8	14	2.000
Universiti Sains Malaysia	Malaysia	11	8	320	29.09	40.00	4	11	0.800
Universiti Kebangsaan Malaysia	Malaysia	9	8	99	11.00	12.38	5	9	1.250
Luminus Technical University College	Jordan	9	8	259	28.78	32.38	7	9	1.750
Abu Dhabi University	United Arab Emirates	9	9	268	29.78	29.78	5	9	1.000
Shahid Beheshti University	Iran	8	8	326	40.75	40.75	6	8	1.000
Universidad de Sevilla	Spain	8	7	96	12.00	13.71	3	8	1.000
Liverpool John Moores University	United Kingdom	8	8	848	106.00	106.00	8	8	1.600
Indian Institute of Management Kashipur	India	7	3	33	4.71	11.00	3	5	1.000
University of Roehampton	United Kingdom	7	7	652	93.14	93.14	7	7	1.400
University of Florence	Italy	7	7	1061	151.57	151.57	4	7	0.800
Universidad de Antioquia	Colombia	7	7	132	18.86	18.86	7	7	1.400
Tunku Abdul Rahman University College	Malaysia	7	5	9	1.29	1.80	2	3	0.400
Norwegian University of Science and Technology	Norway	7	7	1932	276.00	276.00	5	7	0.833
Affiliation NA	Country NA	7	0	0	0.00	0.00	0	0	0.000
Coventry University	United Kingdom	6	6	211	35.17	35.17	5	6	0.833
Chongqing University	China	6	6	106	17.67	17.67	6	6	1.500
Yarmouk University	Jordan	6	1	2	0.33	2.00	1	1	0.333
King's College London	United Kingdom	6	3	3	0.50	1.00	1	1	0.333
Yunnan University of Finance and Economics	China	6	6	64	10.67	10.67	6	6	1.500
Yasar University	Turkey	6	6	53	8.83	8.83	4	6	0.800
Al-Bayt University	Jordan	6	0	0	0.00	0.00	0	0	0.000

Note: TP=total number of publications; NCA=number of contributing authors; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; g=g-index, m=m-index.
Source: Generated by the author(s) using biblioMagika® (Ahmi, 2024)

Table 8 highlights the most productive individual authors in BDAC and firm performance research based on the number of publications (TP) and their citation impacts. The most productive authors by total publications (TP) are Alkhatib, Ayman Wael (10), followed by Norzalita Abd Aziz (5), Taiwen Feng (5), and Sajjad Shokouhyar (5). Ayman Wael Alkhatib (Jordan) is the most prolific author with 10 publications, and Norzalita

Abd Aziz (Malaysia) and Taiwen Feng are the leaders among Asia-based researchers. The most influential authors by their total citations (TC) are Patrick Mikalef (Norway), who stands out with the highest total citations (698) with only 3 publications, which indicates that his works are highly influential and widely cited. The highest citation efficiency, as seen by the average citations per publication (C/P) is held by Patrick Mikalef (232.6), followed by Foropon (93.33), Bryde (93.33), Dubey (93.33) and Wamba (45.00). The highest impact per publication belongs to Mikalef, considered as reinforcing his key role in shaping BDAC literature. The research impact belongs to Ayman Wael Alkhatib, h-index (8) and g-index (10); Feng Taiwen, h-index (5) and g-index (5) and Norzalita Abd Aziz, h-index (4) and g-index (5). This shows consistency in productivity and citation impact. According to the table, there are significant contributions from Asian authors, which shows a strong regional presence from Malaysia, China and Jordan. The BDAC field is driven both by quantity-oriented authors such as Ayman Wael Alkhatib and quality-oriented, highly cited authors such as Mikalef, Foropon, Dubey and Bryde

Table 8: Most Productive Authors

Full Name	Current Affiliation	Country	TP	NCP	TC	C/P	C/CP	*h*	*g*
Alkhatib, Ayman Wael	Luminus Technical University College	Jordan	10	9	286	28.60	31.78	8	10
AN, NA	Affiliation NA	Country NA	7	0	0	0.00	0.00	0	0
Aziz, Norzalita Abd	Universiti Kebangsaan Malaysia	Malaysia	5	5	28	5.60	5.60	4	5
Feng, Taiwen	Harbin Institute of Technology	China	5	5	131	26.20	26.20	5	5
Shokouhyar, Sajjad	Beheshti University	Iran	4	4	179	44.75	44.75	3	4
Chong, Chu-Le	Tunku Abdul Rahman University College	Malaysia	4	2	3	0.75	1.50	1	1
Kazancoglu, Yigit	Yasar University	Turkey	4	4	46	11.50	11.50	3	4
Mangla, Sachin Kumar	O P Jindal Global University	India	3	3	42	14.00	14.00	3	3
Uddin Murad, Md Ahsan	University of Technology Sydney	Australia	3	2	6	2.00	3.00	2	2
Chakraborty, Subrata	University of Technology Sydney	Australia	3	2	6	2.00	3.00	2	2
Foropon, Cyril	Montpellier Business School	France	3	3	280	93.33	93.33	3	3
Mikalef, Patrick	IT-bygget	Norway	3	3	698	232.67	232.67	3	3
Bryde, David J.	Liverpool John Moore's University	United Kingdom	3	3	280	93.33	93.33	3	3
Gupta, Shivam	NEOMA Business School	France	3	3	43	14.33	14.33	2	3
Cetindamar, Dilek	University of Technology Sydney	Australia	3	2	45	15.00	22.50	2	3
Tipu, Syed Awais Ahmad	University of Sharjah	United Arab Emirates	3	3	18	6.00	6.00	3	3
Long, Fei	Guangdong Ocean University	China	3	3	18	6.00	6.00	3	3
Ferraris, Alberto	University of Torino	Italy	3	3	72	24.00	24.00	3	3
Binti Khalid, Haliyana	Universiti Teknologi Malaysia	Malaysia	3	1	1	0.33	1.00	1	1
Dubey, Rameshwar	Liverpool John Moores University	United Kingdom	3	3	280	93.33	93.33	3	3
Song, Jianmin	Chongqing University	China	3	3	53	17.67	17.67	3	3
Wamba, Samuel Fosso	TBS Business School	France	3	3	135	45.00	45.00	3	3
Arias-Pérez, José	Universidad de Antioquia	Colombia	3	3	60	20.00	20.00	3	3
Abdul Rasid, Siti Zaleha	Universiti Teknologi Malaysia	Malaysia	3	1	16	5.33	16.00	1	3

Fantazy, Kamel	The University of Winnipeg	Canada	3	3	18	6.00	6.00	3	3

Note: TP=total number of publications; NCA=number of contributing authors; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; g=g-index, m=m-index.
Source: Generated by the author(s) using biblioMagika® (Ahmi, 2024)

Table 9 and Figure 3 rank journals and conference proceedings based on their contribution to the BDAC field, using productivity and citation impact indicators. There are two journals considered the most productive sources, according to their total publications (TP), with 11 publications each. Those are the Business Process Management Journal and Technological Forecasting and Social Change. Technological Forecasting and Social Change and Information and Management are the most highly cited sources. Information and Management has the highest citation efficiency based on the average citations per publication (CP) and average citations per cited publication (C/CP), with 193.25 citations per article. This makes it a key target for high-impact BDAC research distribution. Technological Forecasting and Social Change has the highest h-index (9) and g-index (11), showing high productivity and high-impact research. Business Process Management Journal also ranks high (h = 8, g = 11), confirming its consistency and influence. Several entries in the table, such as the Proceedings of the Annual Hawaii International Conference on System Sciences, the International Conference on Research and Innovation in Information Systems (ICRIIS), and the 2022 International Conference on Computer Network, Electronic and Automation (ICCNEA 2022), represent conference proceedings rather than journal publications. These conference venues demonstrate the field's engagement with academic events and the dissemination of early-stage research. However, as expected for non-journal sources, these publications generally exhibit lower citation impact than their journal counterparts.

The results show that the concentration of BDAC publications in journals such as Business Process Management Journal, Technological Forecasting and Social Change, Journal of Business Research and Information & Management reveals the conceptual migration of BDAC from predominantly technological topics towards a broader management and strategy domain. These patterns are consistent with the recent reviews that position BDAC as an organizational capability concerned with value creation, innovation, digital transformation, and competitive performance rather than merely with data processing technologies (Huynh et al., 2023; Pathak et al., 2024). The highest citation efficiency of Information & Management can also be regarded in light of the influence of capability-oriented studies such as Mikalef et al (2020), which connects BDAC with dynamic capabilities and operational efficiencies. This journal dominance appears to mirror the field's intellectual transition from technical analytics towards strategic management and organizational transformation.

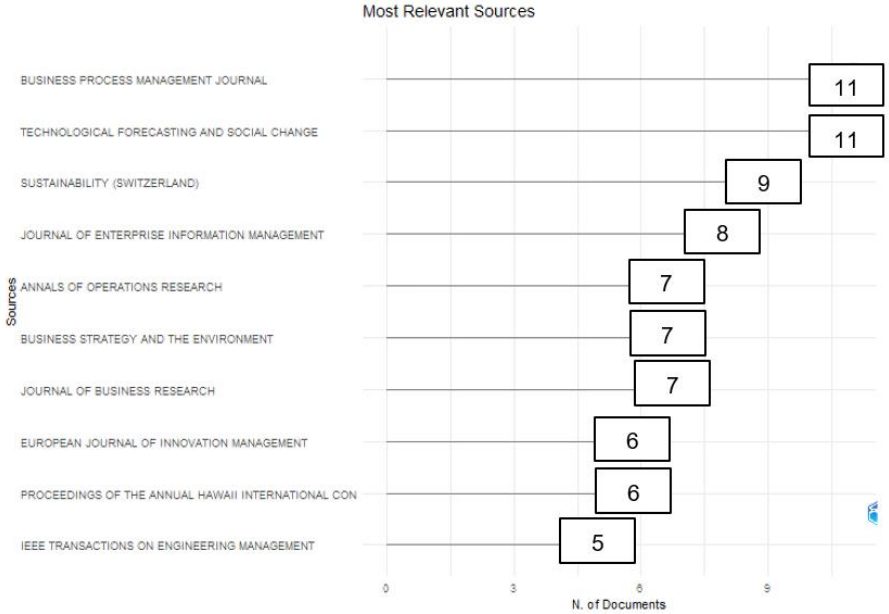
Table 9: Most Productive Source Title

Source Title	TP	NCA	NCP	TC	C/P	C/CP	*h*	*g*	*m*
Business Process Management Journal	11	31	9	269	24.45	29.89	8	11	1.60
Technological Forecasting and Social Change	11	45	11	958	87.09	87.09	9	11	1.50
Sustainability (Switzerland)	9	29	9	189	21.00	21.00	6	9	1.00
Journal of Enterprise Information Management	8	26	6	93	11.63	15.50	5	8	1.00
Business Strategy and the Environment	7	22	6	130	18.57	21.67	5	7	1.67
Journal of Business Research	7	36	6	705	100.7	117.5	4	7	0.67
Annals of Operations Research	7	33	7	181	25.86	25.86	7	7	1.40
Proceedings of the Annual Hawaii International Conference on System Sciences	6	15	4	12	2.00	3.00	2	3	0.33
European Journal of Innovation Management	6	21	6	190	31.67	31.67	5	6	0.83
Lecture Notes in Networks and Systems	5	9	1	2	0.40	2.00	1	1	0.33
IEEE Transactions on Engineering Management	5	18	4	24	4.80	6.00	2	4	0.67
Information and Management	4	16	4	773	193.3	193.3	4	4	0.67

Journal of Manufacturing Technology Management	4	12	3	18	4.50	6.00	2	4	1.00
Benchmarking	4	8	3	30	7.50	10.00	2	4	0.67
International Conference on Research and Innovation in Information Systems, ICRIIS	4	10	2	3	0.75	1.50	1	1	0.20
Industrial Management and Data Systems	4	15	4	84	21.00	21.00	4	4	0.80
International Journal of Productivity and Performance Management	3	7	1	5	1.67	5.00	1	2	0.50
Frontiers in Psychology	3	13	3	57	19.00	19.00	3	3	0.75
Proceedings - 2022 International Conference on Computer Network, Electronic and Automation, ICCNEA 2022	2	2	0	0	0.00	0.00	0	0	0.00
Decision Support Systems	2	8	2	147	73.50	73.50	2	2	0.33

Note: TP=total number of publications; NCA=number of contributing authors; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; g=g-index; m=m-index.
Source: Generated by the author(s) using biblioMagika® (Ahmi, 2024)

Figure 3: Most Relevant Source



Source: Generated by the author(s) using Biblioshiny (Aria, M. & Cucurolo, C. (2017)).

Table 10 illustrates that the top 50 highly cited articles from 2020 to 2024 reflect the intellectual foundations and thematic directions of big data analytics capabilities (BDAC) research in recent years. The most cited work is by Mikalef et al. (2020); the title of the article was *"Exploring the relationship between big data analytics capability and competitive performance: The mediating roles of dynamic and operational capabilities,"* which was published in the Information and Management journal, with 538 citations of 538 and 89.67 citations per year (C/Y). Besides Mikalef, there are other highly cited papers, including Bag et al. (2021) (435 citations), Ciampi et al. (2021) (348), and Awan et al. (2021) (260), emphasizing themes such as supply chain performance, business model innovation, and circular economy decision-making. These articles emphasize research themes such as sustainable supply chain performance, entrepreneurial orientation, and circular economy performance. There are notable appearances multiple times within the top 50 highly cited authors. Several authors who appear multiple times are Mikalef Patrick, who also contributed to the role of information governance in big data analytics-driven innovation; Dubey Rameshwar, who is present in at least a few highly cited works; and Wamba S.F., who has been a notable recurring contributor to big data analytics capabilities, innovation, and performance. These scholars are not only highly cited but also serve as intellectual anchors within the BDAC field.

Table 10: Top 50 Highly Cited Articles

No.	Author(s)	Title	Source Title	TC	C/Y
1	Mikalef P.; Krogstie J.; Pappas I.O.; Pavlou P. (2020)	Exploring the relationship between big data analytics capability and competitive performance: The mediating roles of dynamic and operational capabilities	Information and Management	538	89.67
2	Bag S.; Wood L.C.; Xu L.; Dhamija P.; Kayikci Y. (2021)	Big data analytics as an operational excellence approach to enhance sustainable supply chain performance	Resources, Conservation and Recycling	435	72.50
3	Ciampi F.; Demi S.; Magrini A.; Marzi G.; Papa A. (2021)	Exploring the impact of big data analytics capabilities on business model innovation: The mediating role of entrepreneurial orientation	Journal of Business Research	348	69.60
4	Awan U.; Shamim S.; Khan Z.; Zia N.U.Shariq S.M.; Khan M.N. (2021)	Big data analytics capability and decision-making: The role of data-driven insight on circular economy performance	Technological Forecasting and Social Change	260	52.00
5	Chiappetta Jabbour C.J.; Fiorini P.D.C.; Ndubisi N.O.; Queiroz M.M.; Piato É.L. (2020)	Digitally-enabled sustainable supply chains in the 21st century: A review and a research agenda	Science of the Total Environment	216	36.00
6	Wang C.; Zhang Q.; Zhang W. (2020)	Corporate social responsibility, Green supply chain management and firm performance: The moderating role of big-data analytics capability	Research in Transportation Business and Management	204	34.00
7	Kamble S.S.; Gunasekaran A. (2020)	Big data-driven supply chain performance measurement system: a review and framework for implementation	International Journal of Production Research	189	31.50
8	Yasmin M.; Tatoglu E.; Kilic H.S.; Zaim S.; Delen D. (2020)	Big data analytics capabilities and firm performance: An integrated MCDM approach	Journal of Business Research	160	26.67
9	Yu W.; Zhao G.; Liu Q.; Song Y. (2021)	Role of big data analytics capability in developing integrated hospital supply chains and operational flexibility: An organizational information processing theory perspective	Technological Forecasting and Social Change	159	31.80
10	Mikalef P.; Boura M.; Lekakos G.; Krogstie J. (2020)	The role of information governance in big data analytics-driven innovation	Information and Management	157	26.17
11	Dubey R.; Bryde D.J.; Foropon C.; Tiwari M.; Dwivedi Y.; Schiffling S. (2021)	An investigation of information alignment and collaboration as complements to supply chain agility in humanitarian supply chain	International Journal of Production Research	144	28.80
12	Shamim S.; Zeng J.; Khan Z.; Zia N.U. (2020)	Big data analytics capability and decision-making performance in emerging market firms: The role of contractual and relational governance mechanisms	Technological Forecasting and Social Change	139	23.17
13	Upadhyay P.; Kumar A. (2020)	The intermediating role of organizational culture and internal analytical knowledge between the capability of big data analytics and a firm's performance	International Journal of Information Management	134	22.33
14	Dubey R.; Bryde D.J.; Dwivedi Y.K.; Graham G.; Foropon C. (2022)	Impact of artificial intelligence-driven big data analytics culture on agility and resilience in humanitarian supply chain: A practice-based view	International Journal of Production Economics	124	31.00
15	Yu W.; Wong C.Y.; Chavez R.; Jacobs M.A. (2021)	Integrating big data analytics into supply chain finance: The roles of information processing and data-driven culture	International Journal of Production Economics	121	24.20

16	Jha A.K.; Agi M.A.N.; Ngai E.W.T. (2020)	A note on big data analytics capability development in supply chain	Decision Support Systems	115	19.17
17	Behl A.; Gaur J.; Pereira V.; Yadav R.; Laker B. (2022)	Role of big data analytics capabilities to improve sustainable competitive advantage of MSME service firms during COVID-19 – A multi-theoretical approach	Journal of Business Research	102	25.50
18	Ashaari M.A.; Singh K.S.D.; Abbasi G.A.; Amran A.; Liebana-Cabanillas F.J. (2021)	Big data analytics capability for improved performance of higher education institutions in the Era of IR 4.0: A multi-analytical SEM & ANN perspective.	Technological Forecasting and Social Change	95	19.00
19	Bahrami M.; Shokouhyar S. (2022)	The role of big data analytics capabilities in bolstering supply chain resilience and firm performance: a dynamic capability view	Information Technology and People	90	22.50
20	Akter S.; Gunasekaran A.; Wamba S.F.; Babu M.M.; Hani U. (2020)	Reshaping competitive advantages with analytics capabilities in service systems	Technological Forecasting and Social Change	89	14.83
21	Olabode O.E.; Boso N.; Hultman M.; Leonidou C.N. (2022)	Big data analytics capability and market performance: The roles of disruptive business models and competitive intensity	Journal of Business Research	87	21.75
22	Mariani M.M.; Nambisan S. (2021)	Innovation Analytics and Digital Innovation Experimentation: The Rise of Research-driven Online Review Platforms	Technological Forecasting and Social Change	82	16.40
23	AlNuaimi B.K.; Khan M.; Ajmal M.M. (2021)	The role of big data analytics capabilities in greening e-procurement: A higher-order PLS-SEM analysis	Technological Forecasting and Social Change	82	16.40
24	Khan A.; Tao M.; Li C. (2022)	Knowledge absorption capacity's efficacy in enhancing innovation performance through big data analytics and digital platform capability	Journal of Innovation and Knowledge	75	18.75
25	Behl A. (2022)	Antecedents to firm performance and competitiveness using the lens of big data analytics: a cross-cultural study	Management Decision	71	17.75
26	Alkhatib A.W.; Valeri M. (2024)	Can intellectual capital promote the competitive advantage? Service innovation and big data analytics capabilities in a moderated mediation model	European Journal of Innovation Management	68	34.00
27	Al-Khatib A.W. (2022)	Can big data analytics capabilities promote a competitive advantage? Green radical innovation, green incremental innovation and data-driven culture in a moderated mediation model	Business Process Management Journal	60	15.00
28	Shokouhyar S.; Seddigh M.R.; Panahifar F. (2020)	Impact of big data analytics capabilities on supply chain sustainability: A case study of Iran	World Journal of Science, Technology and Sustainable Development	58	9.67
29	Su X.; Zeng W.; Zheng M.; Jiang X.; Lin W.; Xu A. (2022)	Big data analytics capabilities and organizational performance: the mediating effect of dual innovations	European Journal of Innovation Management	57	14.25
30	Mugiraneza T.; Nascetti A.; Ban Y. (2020)	Continuous monitoring of urban land cover change trajectories with Landsat time series and landtrendr-google earth engine cloud computing	Remote Sensing	56	9.33
31	Zhang D.; Pan S.L.; Yu J.; Liu W. (2022)	Orchestrating big data analytics capability for sustainability: A study of air pollution management in China	Information and Management	52	13.00
32	Zhu C.; Du J.; Shahzad F.; Wattoo M.U. (2022)	Environmental Sustainability Is a Corporate Social Responsibility: Measuring the Nexus between Sustainable Supply Chain Management, Big Data	Sustainability (Switzerland)	51	12.75

		Analytics Capabilities, and Organizational Performance			
33	Gu V.C.; Zhou B.; Cao Q.; Adams J. (2021)	Exploring the relationship between supplier development, big data analytics capability, and firm performance	Annals of Operations Research	51	10.20
34	Xiao X.; Tian Q.; Mao H. (2020)	How the interaction of big data analytics capabilities and digital platform capabilities affects service innovation: A dynamic capabilities view	IEEE Access	50	8.33
35	Horng J.-S.; Liu C.-H.; Chou S.-F.; Yu T.-Y.; Hu D.-C. (2022)	Role of big data capabilities in enhancing competitive advantage and performance in the hospitality sector: Knowledge-based dynamic capabilities view	Journal of Hospitality and Tourism Management	49	12.25
36	Aljumah A.I.; Nuseir M.T.; Alam M.M. (2021) - RETRACTED	Organizational performance and capabilities to analyze big data: do the ambidexterity and business value of big data analytics matter?	Business Process Management Journal	49	9.80
37	Ramadan M.; Shuqqo H.; Qtaishat L.; Asmar H.; Salah B. (2020)	Sustainable competitive advantage driven by big data analytics and innovation	Applied Sciences (Switzerland)	46	7.67
38	Al-Khatib A.W. (2022)	Big data analytics capabilities and green supply chain performance: investigating the moderated mediation model for green innovation and technological intensity	Business Process Management Journal	45	11.25
39	Albergaria M.; Chiappetta Jabbour C.J. (2020)	The role of big data analytics capabilities (BDAC) in understanding the challenges of service information and operations management in the sharing economy: Evidence of peer effects in libraries	International Journal of Information Management	45	7.50
40	Xing Y.; Wang X.; Qiu C.; Li Y.; He W. (2022)	Research on opinion polarization by big data analytics capabilities in online social networks	Technology in Society	43	10.75
41	Zhang H.; Song M.; He H. (2020)	Achieving the success of sustainability development projects through big data analytics and artificial intelligence capability	Sustainability (Switzerland)	43	7.17
42	Ciasullo M.V.; Montera R.; Douglas A. (2022)	Building SMEs' resilience in times of uncertainty: the role of big data analytics capability and co-innovation	Transforming Government: People, Process and Policy	41	10.25
43	Cetindamar D.; Shdifat B.; Erfani E. (2022)	Understanding Big Data Analytics Capability and Sustainable Supply Chains	Information Systems Management	41	10.25
44	Sun B.; Liu Y. (2020)	Business model designs, big data analytics capabilities and new product development performance: evidence from China	European Journal of Innovation Management	41	6.83
45	Jiang Y.; Feng T.; Huang Y. (2024)	Antecedent configurations toward supply chain resilience: The joint impact of supply chain integration and big data analytics capability	Journal of Operations Management	39	19.50
46	Bhatti S.H.; Ahmed A.; Ferraris A.; Hirwani Wan Hussain W.M.; Wamba S.F. (2022)	Big data analytics capabilities and MSME innovation and performance: A double mediation model of digital platform and network capabilities	Annals of Operations Research	38	9.50
47	Sahoo S.; Upadhyay A.; Kumar A. (2023)	Circular economy practices and environmental performance: Analysing the role of big data analytics capability and responsible research and innovation	Business Strategy and the Environment	37	12.33
48	Xin X.; Miao X.; Cui R. (2023)	Enhancing sustainable development: Innovation ecosystem coopetition, environmental resource orchestration, and disruptive green innovation (the moderating effect of BDAC)	Business Strategy and the Environment	37	12.33

49	Wang T.; Lin X.; Sheng F. (2022)	Digital leadership and exploratory innovation: From the dual perspectives of strategic orientation and organizational culture	Frontiers in Psychology	35	8.75
50	Yu D.; Tao S.; Hanan A.; Ong T.S.; Latif B.; Ali M. (2022)	Fostering Green Innovation Adoption through Green Dynamic Capability: The Moderating Role of Environmental Dynamism and Big Data Analytic Capability	International Journal of Environmental Research and Public Health	35	8.75

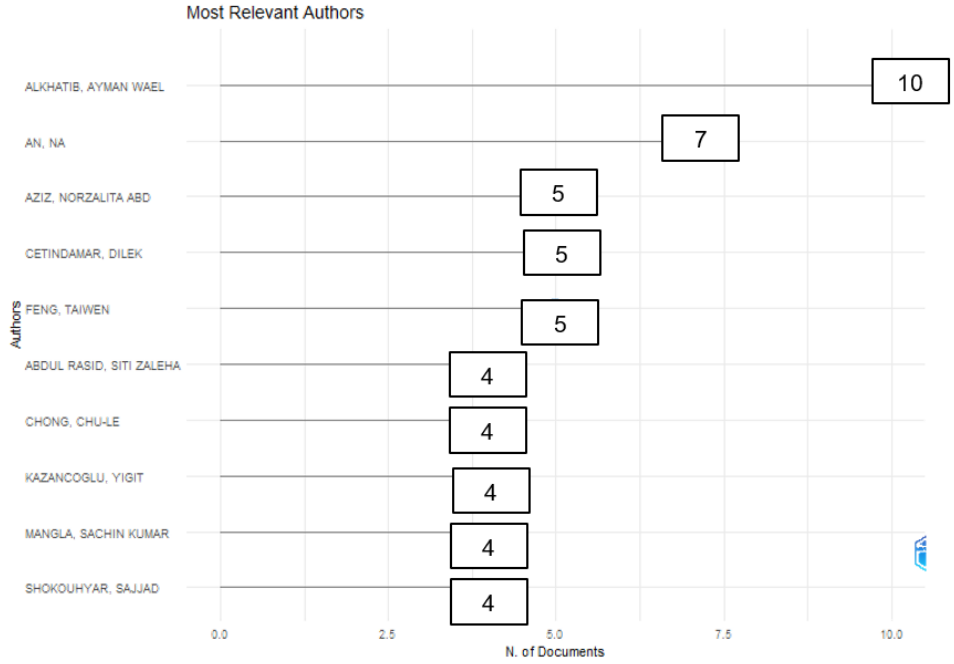
Source: Generated by the author(s) using biblioMagika® (Ahmi, 2024)

Refer to the following table 11, which shows the key thematic areas of the top-cited articles that revolve around the recurring topics. To conclude, the findings of the top 50 cited documents from 2020 to 2024 confirm that the BDAC field is advancing rapidly with strong citation performance; the key themes revolve around sustainability, performance impact, innovation, and technological integration; and methodologically and theoretically, the field has matured, demonstrating multidimensional relevance across domains.

Table 11: BDAC Research Themes

Theme	Sample Articles
Firm Performance & Decision-Making	Mikalef et al. (2020); Shamim et al. (2020); Yasmin et al. (2020); Bag et al. (2021); Wang et al. (2020); Kamble et al. (2020); Shamim et al. (2020); Upadhyay & Kumar (2020); Ashaari et al. (2021); Bahrami & Shokouyar (2022); Olabode et al. (2022); Khan et al. (2022); Behl A. (2022); Su et al. (2022); Zhu et al. (2022); Gu et al. (2021); Horng et al. (2022)—Hospitality industry; Aljumah et al. (2021); Alkhatib (2022); Sun & Liu (2020); Bhatti et al (2022); Sahoo et al. (2023)
Sustainability & Green Supply Chains & Green Innovation	Bag et al. (2021); C.J. Chiappetta Jabbour et al. (2020); Wang et al. (2020); Behl et al. (2022); Zhu et al. (2022); Cetindamar et al. (2022); Wang et al. (2020); AlNuaimi et al. (2021); Al Khatib (2022); Xin et al. (2023); Yu et al. (2022)
Business Model Innovation	Ciampi et al. (2021); Al Khatib (2022); Olabode et al. (2022); Sun B (2020)
Artificial Intelligence Integration	Dubey et al. (2022); Zhang et al. (2022)
Healthcare and Sectoral Applications	Yu et al. (2021)

Figure 4: **Most Relevant Authors**



Source: Generated by the author(s) using Biblioshiny (Aria, M & Cucurolo, C. (2017)

Table 12 and Figure 4 represent the most relevant authors in the field of big data analytics capabilities (BDAC). The tables were ranked by the number of documents contributed to the particular research field. The relevancies were measured both in terms of total publications and fractionalized authorship, which refers to co-authorship and shared contributions. The top of the list, with 10 publications and a fractionalized score of 7.67, is Alkhatib, Ayman Wael, indicating a high degree of individual contribution in the sustainability, green supply chain, and innovation context. Next, AN, NA, with 7 publications and a fractional score of & shows a consistent solo or primary authorship pattern, although further investigation may be needed to verify the identity or completeness of the author entry. According to Ahmi (2024), to address the issue of documents with no author name, "AN" refers to "Author Name", and "NA" stands for "Not Available". Therefore, in cleaning the dataset extracted from Scopus, the reference to Ahmi's (2024) suggestions was adopted to address the issue of missing values. Other prolific contributors with 5 or more publications include Aziz; Norzalita Abd; Cetindamar, Dilek; and Feng. Taiwen, all showing moderate fractional authorship scores (~1.6), suggesting frequent collaboration. Authors such as Chong, Chu-Le, Shokouhyar, Sajjad, Abdul Rasid, and Siti Zaleha each have 4 publications with fractionalized scores between 1.1 and 1.6, indicating active participation in multi-author teams. Kazancoglu, Yigit, and Mangla, Sachin Kumar, while having the same number of publications (4), show lower fractional scores (0.85). The data indicate that BDAC research is characterized by both concentrated individual contributions and highly collaborative environments.

Table 12: Most Relevant Authors

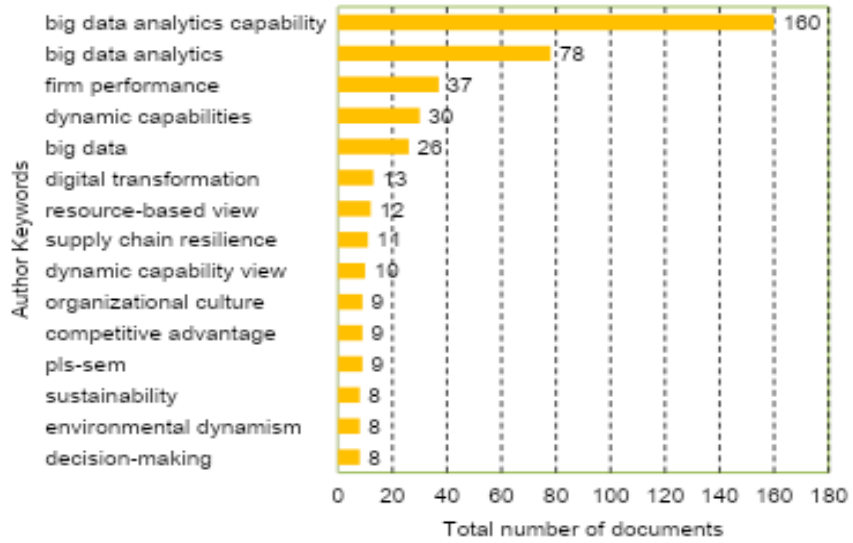
Authors	Articles	Articles Fractionalized
ALKHATIB, AYMAN WAEL	10	7.67
AN, NA	7	7
AZIZ, NORZALITA ABD	5	1.58
CETINDAMAR, DILEK	5	1.67
FENG, TAIWEN	5	1.67
ABDUL RASID, SITI ZALEHA	4	1.12
CHONG, CHU-LE	4	1.17
KAZANCOGLU, YIGIT	4	0.85
MANGLA, SACHIN KUMAR	4	0.85
SHOKOUHYAR, SAJJAD	4	1.67

This section shows a visual representation to quickly identify the most frequently used keywords, enabling a clearer understanding of the key topics and themes within the dataset.

Figure 5 and Table 13 present the 15 most frequently used keywords across the dataset. These keywords revealed the prominent themes in the BDAC literature, and a keyword frequency analysis was performed using the authors' commonly used terms. The most often used keyword is "big data analytics capability", which appears 160 times (11.71%). This establishes it as the field's conceptual anchor. The larger term "big data analytics" ranks second with 78 occurrences (5.71%), indicating a broader perspective that covers applications and methodologies beyond capability building. "Firm performance" (37 occurrences, 2.71%) is the primary dependent variable of interest, indicating that academics frequently investigate how BDAC affects business outcomes. Several high-ranking keywords represent theoretical frameworks and strategic constructs. According to the data, the terms "dynamic capabilities" (30 instances) and "dynamic capability view" (10 mentions) demonstrate the extensive use of dynamic capabilities theory to frame BDAC as an adaptive asset. "Resource-based view" (12 occurrences) is consistent with studies stressing BDAC as a distinct organizational resource that contributes to competitive advantage. "Organizational culture," "decision-making," and "competitive advantage" represent the conceptual diversity of BDAC literature, bridging operational, behavioral, and strategic dimensions. There are growing topics that have arisen as frequent buzzwords, such as "digital transformation" (13), "supply chain resilience" (11), "sustainability" (8), and "environmental dynamism" (8), indicating a rising integration of BDAC into broader organizational and environmental contexts. The presence of "PLS-SEM" (9) among the top keywords represents a methodological trend, showing that partial least squares structural equation modelling is a popular analytical tool in BDAC research. The diversity and ranking of keywords indicate a transition in the field from technical and infrastructure debates

to performance, transformation, and strategic alignment topics. It also implies an increasing interest in transdisciplinary applications, particularly those connected to resilience, sustainability and digital innovation.

Figure 5: Frequency Distribution of Top 15 Author Keywords



Source: Generated by the author(s) using biblioMagika® (Ahmi, 2024)

Table 13: Top Author Keywords

Author Keywords	Count	Percentage
big data analytics capability	160	11.71%
big data analytics	78	5.71%
firm performance	37	2.71%
dynamic capabilities	30	2.20%
big data	26	1.90%
digital transformation	13	0.95%
resource-based view	12	0.88%
supply chain resilience	11	0.81%
dynamic capability view	10	0.73%
organizational culture	9	0.66%
competitive advantage	9	0.66%
pls-sem	9	0.66%
sustainability	8	0.59%
environmental dynamism	8	0.59%
decision-making	8	0.59%

The co-occurrence keyword analysis reveals several key areas for future research in big data analytics capability. Table 14 summarizes the co-occurrence keyword analysis conducted on big data analytics capability. The co-occurrence analysis revealed six distinct thematic clusters, each representing a core research stream in BDAC literature. The keyword structure provides further evidence of the field's theoretical consolidation. Rialti et al. (2019) identified capabilities, decision-making, supply chain management, and business process management as important components of the earlier big data literature. Aboelmaged and Mouakket (2020) also identified dynamic capabilities and the resource-based view (RBV) among the theoretical frameworks employed in big data analytics (BDA) research but argued that the field lacked consensus and remained dispersed across models. In the present study, dynamic capabilities and RBV are considered relevant, and both appear among the most frequently occurring author keywords. At the same time,

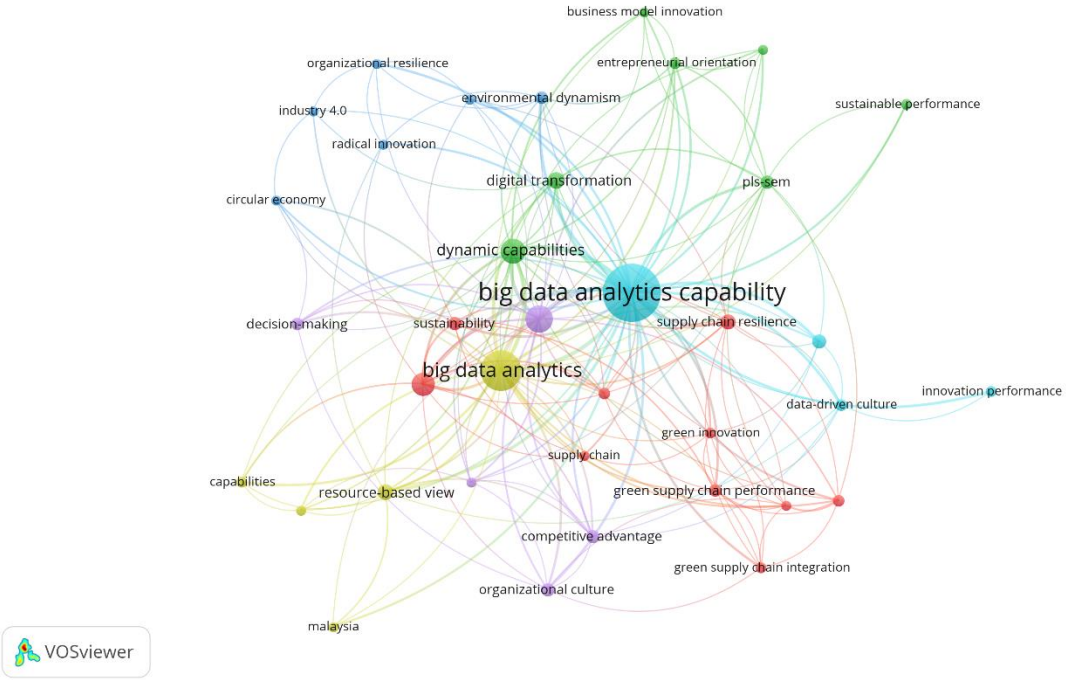
newer terms such as digital transformation, supply chain resilience, sustainability, and environmental dynamism demonstrate that the theoretical conversation is expanding towards adaptation and sustainability.

Table 14: Co-occurrence Author Keywords Analysis on Big Data Analytics Capability

Cluster Number	Cluster Color	Cluster Label	Number of Keywords	Representative Keywords	
1	Red	Supply Chain and Sustainability	8	Green Innovation Green Supply Chain Integration Green Supply Chain Performance Supply Chain Supply Chain Agility Supply Chain Management Supply Chain Resilience Sustainability	This cluster (red) emphasizes the role of BDAC in fostering sustainable and resilient supply chains. Illustrate how BDAC contributes to both operational efficiency and environmental stewardship.
2	green	Organizational and Cultural Integration	7	Business Model Innovation Digital Transformation Dynamic Capabilities Entrepreneurial Orientation Organizational Agility PLS-SEM Sustainable Performance	The green cluster focuses on the internal organizational enablers of BDAC effectiveness. It highlights business model innovation, digital transformation, dynamic capabilities, and organizational agility as critical drivers, often supported by PLS-SEM methodologies to study these relationships.
3	blue	Circular Economy & Industry 4.0	6	Circular Economy Environmental Dynamism Industry 4.0 Organizational Resilience Radical Innovation SMES	This blue cluster reflects the integration of BDAC within broader technological and societal paradigms. Indicates a growing focus on sustainability-driven innovation and adaptation to the fourth industrial revolution.
4	yellow	Business Value, Resources & Capabilities	5	Big data analytics Business value Capabilities Malaysia Resource-based view	The yellow cluster centers on BDAC as a strategic resource and capability, contributing to organizational value creation. Highlight the theoretical and empirical investigations of BDAC as a source of competitive advantage.
5	Purple	Firm Performance & Competitive Advantage	5	Competitive Advantage Decision-Making Firm Performance Innovation Organizational Culture	This purple cluster examines the impact of BDAC on firm-level outcomes. Underscoring BDAC's role in improving both financial and strategic performance metrics.
6	Turquoise	Data-driven culture and Dynamic Capability	4	Big data analytics capability Data-driven culture Dynamic capability view Innovation performance	The turquoise cluster explores how data-driven culture and dynamic capability view contribute to innovation performance. This stream underscores the human and cultural dimensions that underpin the successful deployment of BDAC in achieving strategic goals.

Source: Generated by the author(s) using VOSviewer

Figure 6: Network visualization map of the Co-occurrence Author Keywords Analysis on Big Data Analytics Capability



Source: Generated by the author(s) using VOSviewer

Table 15: Comparison of previous studies in relation to present study

Study	Main emphasis	Main themes/findings	Relationship to present study
Rialti et al. (2019)	Big data and dynamic capabilities	Supply chain, knowledge management, decision-making, BPM, analytics	The present study confirms these foundations but finds stronger sustainability and resilience themes
Aboelmaged & Mouakket (2020)	BDA adoption theories	RBV, dynamic capabilities and multiple overlapping adoption models	Present results suggest greater theoretical consolidation around RBV/DCT
Inamdar et al. (2021)	BDA adoption, Sectoral adoption	Manufacturing, services, sustainable supply-chain opportunities	The sustainable supply chain now appears as a major established cluster
Fauzi et al. (2023)	BDA and HRM	Firm performance, BDA challenges, data-driven culture	The present study shows these themes extending beyond HRM
Murad et al. (2023)	BDAC and sustainability	Developed-country concentration; performance, innovation, supply chain	The present study shows stronger Asian participation and sustainability centrality
Huynh et al. (2023)	Conceptual status of BDAC systematic review	Fragmented theoretical base, survey dominance	The present study shows RBV/DCT as clear intellectual anchors but increasing thematic diversification
Pathak et al. (2024)	Domain and knowledge structure	RBV/DCT, antecedents, consequences, advanced analytics, environmental dynamics	The present study corroborates these and identifies green supply chains, circular economy and data-driven culture as prominent recent themes

Discussion

This study provides an updated mapping of the intellectual landscape of Big Data Analytics Capabilities (BDAC) research between 2020 and 2024 through a comprehensive bibliometric analysis, addressing seven key research questions. The findings reveal a broader transformation in how BDAC is conceptualized and applied, rather than just viewing the bibliometric indicators solely as publication productivity measurements. Overall, the results suggest that BDAC research has progressed from emphasis on technological adoption and analytics infrastructure towards an organizational capability perspective. This highlights the concern with value creation, dynamic capabilities, firm performance, resilience, sustainability, and digital transformation. The results have addressed the key research questions proposed earlier.

The first question examined the trends in publication for BDAC research. The results showed substantial growth during the five years. The number of publications increased from 30 documents in 2020 to 94 in 2024. Out of 281 documents included in the analysis, there are approximately one-third of the total (94 publications) produced in 2024. This shows that BDAC is growing and developing from a relatively specialized research topic into an increasingly established area within information systems, strategic management, and organizational studies. This is aligned with previous reviews and also indicates that the field has progressed well. For instance, previous studies characterized earlier big data analytic (BDA) adoption research as relatively dispersed across different domains and theoretical models, with considerable overlap and limited consensus (Aboelmaged and Mouakket, 2020). Additionally, Rialti et al. (2019) observed that research linking big data with dynamic capabilities has identified the research streams involving supply chain management, knowledge management, decision-making, and business process management. This trajectory reflects the increasing scholarly interest and recognition of BDAC as a crucial organizational capability, especially in the context of digital transformation and firm performance. Although the number of citations per publication has declined in recent years, a pattern typical in bibliometrics, since older works have had more time to accrue citations, the growing publication volume suggests a vibrant and expanding research field.

The second research question concerned the most prominent authors and the themes associated with their work. The results reveal an important distinction between productivity and intellectual influence. The analysis identified Ayman Wael Alkhatib as the most prolific author, with 10 publications, often focusing on sustainability, innovation, and green supply chains. Other prominent contributors include Norzalita Abd Aziz and Taiwen Feng, who are notable for their collaborative and cross-disciplinary work. However, in terms of influence, Patrick Mikalef, despite having fewer publications, stands out with the highest citation impact, reflecting the foundational and highly cited nature of his contributions on BDAC and competitive performance. Together, these authors demonstrate the field's dual orientation toward both quantity and high-impact quality.

The third research question examined the geographical and institutional distribution of BDAC scholarship. The research landscape is dominated geographically by China, which leads in both total publications and institutional productivity, notably through Jiangsu University and Harbin Institute of Technology. However, institutions like the Norwegian University of Science and Technology and the University of Florence exhibit exceptional citation impact despite fewer publications. Among countries, China is followed by Malaysia and the UK in publication count, with the UK showing stronger citation efficiency, underscoring its emphasis on impactful research.

The fourth research question concerned the journals that are most active in BDAC research. The prominence of Business Process Management Journal, Technological Forecasting and Social Change, Journal of Business Research, Information & Management, and related management and information systems outlets provide evidence of the disciplinary evolution of BDAC. These outlets have become central to the dissemination of BDAC research, reflecting their alignment with the field's strategic, technological, and organizational focus.

The fifth research question examined the most influential publications and their underlying themes. The highly cited documents identified in this study indicate that the intellectual foundation of contemporary BDAC research is strongly capability-oriented. The most cited article is by Mikalef et al. (2020), which explored the mediating role of dynamic and operational capabilities in the BDAC–performance relationship. Other highly cited works delve into themes such as sustainable supply chains (Bag et al., 2021), business model innovation (Ciampi et al., 2021), and circular economy performance (Awan et al., 2021). Collectively, the top-cited works

highlight the centrality of BDAC in driving organizational performance, innovation, and sustainability. From the highly cited authors' analysis, this study has identified 5 research themes that are associated based on the similar topic that has been discussed in a few research studies by the collective top highly cited articles, which are the following: 1) Firm Performance & Decision-Making, 2) Sustainability & Green Supply Chains & Green Innovation, 3) Business Model Innovation, 4) Artificial Intelligence Integration, and 5) Healthcare and Sectoral Applications

The sixth research question examined the most common keywords and their evolution. The keyword structure provides some of the strongest evidence that the BDAC field is undergoing theoretical and practical transformation. Keyword analysis reveals that “big data analytics capability” is firmly established as the conceptual core of the field. Other prominent keywords such as “firm performance", “dynamic capabilities", “digital transformation", and “sustainability” point to the expanding theoretical and practical scope of BDAC research. The increasing appearance of terms like “supply chain resilience” and “environmental dynamism” suggests a growing interest in how BDAC enables organizational adaptation to volatile environments. The emergence of sustainability-related terminology is particularly significant. A previous study concluded that the relationship between BDAC and sustainability remained largely underexplored (Murad et al., 2023). Previous research has been found to be concerned with firm performance, innovation-related and supply chain resilience. The present study's analysis suggests that sustainability, green supply chain integration, green innovation, and circular economy, as well as organizational performance, are closely interconnected to form identifiable thematic structures.

The seventh research question examined the thematic clusters emerging from keyword co-occurrence analysis. Six major clusters were identified from the co-occurrence keyword, and thematic cluster analyses uncovered dominant research themes as referenced in Table 15 and Figure 6. These clusters illustrate the multidimensional relevance of BDAC, spanning supply chain resilience and fostering sustainability practices; internal organizational enablers of BDAC effectiveness; growing focus on sustainability-driven innovation; and adaptation to the fourth industrial revolution; BDAC as a source of competitive advantage; BDAC’s role in improving both financial and strategic performance metrics; and successful deployment of BDAC in achieving strategic goals.

Overall, the results and findings from this bibliometric study suggest that BDAC research has evolved through several overlapping stages. Previous studies concentrated largely on an adoption-oriented phase, whereas the present findings indicate that the field is now entering into a broader strategic transformation-oriented phase. Firm performance and competitive advantage remain the focal point, but they coexist with organizational agility, digital transformation, resilience, environmental dynamism, green innovation, sustainable performance, circular economy, and data-driven culture.

5. Conclusion and Implications

Theory and Theory Development

This study shows that big data analytics capability (BDAC) is evolving from a simple technological asset into a core strategic and integrative capability for organizations. It emphasizes that BDAC now supports digital transformation and helps achieve sustainable performance (Shokouhyar et al., 2020), as highlighted in recent research. Existing research proposes that BDACs enable firms to generate insight that can help strengthen their dynamic capabilities, which, in turn, positively impact marketing and technological capabilities; therefore, a strong BDAC can help firms build a competitive advantage (Mikalef et al., 2020). It is acknowledged that there are relevancies of classical frameworks such as the resource-based view (RBV) and dynamic capabilities theory (DCT) in explaining how organizations create and sustain competitive advantage through data-driven insights. However, there have been noticeable themes, according to studies that have uncovered them, encompassing different areas or themes. For instance, sustainability, agility, and supply chain performance suggest that BDAC has outgrown single-theory explanations. Theoretically, future research could therefore move toward multi-theoretical integration, combining RBV, stakeholder theory, and institutional perspectives, and organizational information processing theory perspectives (OIPT) to capture the interplay between analytics capabilities, governance, and contextual factors in dynamic markets. Such theoretical enrichment can deepen understanding of how firms in developing regions transform technological potential into adaptive and resilient organizational competencies.

Readers and Researchers

For scholars and readers, the findings provide a comprehensive map of the intellectual and thematic structure of BDAC research and clarify its most active contributors, evolving keywords, and emerging research hotspots. The identified clusters, spanning firm performance & decision-making, sustainability & green supply chains & green innovation, business model innovation, artificial intelligence integration, and healthcare and sectoral applications, illustrate where academic attention is converging and where conceptual gaps remain. In particular, limited research on BDAC implementation contexts presents opportunities for scholars to explore how cultural, institutional, and economic diversity influence capability development and analytics-driven decision-making. The trend toward cross-disciplinary collaboration is evident from co-authorship networks, which also indicates that future research will benefit from partnerships that bridge technology, management, and social science disciplines. This paper thus serves as a knowledge guide for researchers seeking to position their work within global BDAC discourse while contributing region-specific insights.

Business and management practices

For practitioners and policymakers, the findings highlight that BDAC is not solely a technological function but a strategic enabler of organizational transformation. Firms that successfully embed analytics into their management systems demonstrate higher levels of innovation, decision agility, and sustainability performance. The recurring themes of firm performance & decision-making, sustainability & green supply chains & green innovation, business model innovation, artificial intelligence integration, and healthcare and sectoral applications underscore that competitive advantage increasingly depends on intelligent data orchestration and human capabilities. For Asia-Pacific businesses, particularly those in emerging markets, this implies that investments in BDAC should extend beyond technology to include managerial competencies, data governance frameworks, and cross-functional integration. Moreover, the alignment of BDAC with ESG and sustainability objectives presents a critical pathway for firms to enhance both profitability and societal value. Policymakers can also leverage these insights to support capability-building initiatives that strengthen regional competitiveness in the data-driven economy.

Conclusion

The bibliometric analysis conducted confirms that BDAC research has evolved into a mature and interdisciplinary field that bridges technology, strategy, and sustainability. While the field is growing rapidly in publication output and thematic diversity, future studies could further explore underrepresented areas, such as BDAC's application in arts, medicine, and emerging economies, and adopt more longitudinal and experimental methodologies to deepen our understanding of its long-term impact. This study contributes to analyzing the trends between the years 2020 and 2024. It has offered a list of authors to be referred to for the BDAC topic in research, highlighting the highly cited and their contributions. The findings have come up with thematic cluster analyses that uncovered five dominant research themes, which can be referred to by researchers to come up with upcoming research in the same field. The fewest cited articles are from the Healthcare and Sectoral Applications, which can be one of the areas to focus on in future research that relates to the application of digital technologies such as big data analytics and organizational capabilities.

Limitations of the study

The study has faced a few limitations in collecting data from Scopus, and finalizing data for each article is time-consuming, as the keyword search on BDAC is not limited to only the title search but also the abstract. It is useful to confirm the search by looking at the abstract of the article, as not all titles present the keyword on big data analytics capability, but the paper does discuss BDAC. If the article is removed, it will affect the total number of analyses. Therefore, it is advisable not to exclude the article based on the title search but to reconfirm the article content from the abstract.

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The Role of MOOC-Based Supplementary Learning in Enhancing Student Academic Performance: Evidence from Non-Business Students in an Entrepreneurship Course

Mutiiah Mohamad[1], *Farah Lina Azizan[1], Syazwani Ya[1], Wan Nurulasiah Wan Mustapa[2], Emeela Wae-esor[3]
[1]Faculty of Business and Management, UiTM Cawangan Perlis, Malaysia
[2]Faculty of Business & Communication, Universiti Malaysia Perlis, Malaysia
[3]Faculty of International Studies, Prince of Songkla University, Thailand
Email: mutiiah@uitm.edu.my, *farahlina@uitm.edu.my, syazwani446@uitm.edu.my, wannurulasiah@unimap.edu.my, emeela.w@phuket.psu.ac.th
Corresponding Author: Dr Farah Lina Azizan

Abstract: The increasing integration of digital technologies into higher education has created new opportunities for institutions to complement conventional classroom instruction with flexible and student-centered learning resources. This study examines the effectiveness of a curriculum-aligned MOOC-based supplementary learning intervention in supporting students' conceptual understanding and academic performance. The study was conducted among undergraduate non-business students enrolled in an entrepreneurship course at a Malaysian higher education institution. A one-group pre-test and post-test design was used. Aggregated data on students' conceptual understanding, quiz performance and satisfaction were analyzed using descriptive and comparative statistics. The results show that the MOOC-based supplementary learning intervention was found to be associated with improvements in students' conceptual understanding and academic performance. The findings also indicated a high level of satisfaction with the digital learning intervention, particularly in terms of accessibility and the usefulness of multimedia learning resources. The results suggest that curriculum-aligned MOOC-based supplementary learning can provide beneficial support for continuing learning beyond traditional classroom instruction and improve students' engagement with course content. The study contributes to the growing knowledge literature by demonstrating the potential of MOOC-based supplementary learning as a practical digital learning approach in higher education.

Keywords: *Massive Open Online Course, digital learning, academic performance, student achievement, blended learning.*

1. Introduction and Background

The quick development of digital technologies has substantially reformed the higher education setting, influencing the way students gain access, interact with and apply knowledge (de Bruijn-Smolders & Prinsen 2024). Although face-to-face learning remains a core component in university education, the use of digital learning resources has become more integrated, and students are now able to access educational content in a more flexible and personalized way. This transformation has contributed to the growing adoption of blended learning, self-paced learning and other methods of technology-enhanced instruction in higher education institutions (Elmabaredy & Gencel, 2024).

Massive Open Online Courses (MOOCs) are an important form of enhanced technology learning among the various digital learning approaches adopted by higher education. MOOCs offer a structured learning environment that can contain video-based course content, interactive materials, learning activities, formative assessment and additional resources. MOOCs are initially linked with open and large-scale online learning, but their applications are now growing at the institutional and course levels (Dinh & Phuong, 2024).

Within university teaching, MOOCs can serve as supporting materials that complement rather than replace face-to-face instruction. This method allows students to retrieve course materials beyond scheduled classroom sessions and provides opportunities for repeated exposure to concepts that may require additional explanation (Lo Hew, 2021). The flexibility of digital learning may be specifically beneficial in higher education environments where students possess different levels of prior knowledge, learning preferences and academic preparedness.

The effectiveness of digital learning, however, does not only relate to the availability of online content. The design and integration of the learning intervention also play a crucial role. Digital learning materials that are

aligned with the learning outcomes of the course and have pedagogically designed learning activities can have a higher educational value than digital learning materials that are simply presented without pedagogical orientation (Vo et al., 2017).

Recent studies have demonstrated the potential of blended learning to support student engagement and learning outcomes in higher education. A systematic review of blended learning interventions reported moderate to high positive effects on different aspects of student engagement and learning outcomes (Moreira & Lima, 2024). Similarly, previous meta-analytic evidence has demonstrated a positive effect of blended learning on higher education students' academic performance compared with conventional classroom instruction (Bingolbali et al., 2025).

Conversely, the effectiveness of digital learning interventions may depend on how they are designed and integrated into the existing learning environment (Ritz et al., 2023). Digital learning resources are unlikely to produce optimal outcomes merely because they are available online. Instead, the learning materials need to be aligned with course learning outcomes, structured according to students' learning needs and supported by appropriate learning activities and assessment mechanisms (Ali, 2018; Hristov et al., 2023).

This concern is particularly significant in entrepreneurship education. Entrepreneurship courses regularly involve students combining theoretical knowledge with practical application (Jan, 2024; Rodrigues, 2023). Students may be anticipated to understand entrepreneurial concepts, identify business opportunities, develop business ideas, use digital marketing platforms, manage basic finances and operate an online business. Thus, students require both conceptual understanding and the ability to apply knowledge from practical perspectives.

According to Li et al. (2025), the challenge becomes more significant when entrepreneurship courses are taken by students from non-business academic backgrounds. In Malaysian higher education, university-wide entrepreneurship courses are often offered to students from diverse academic disciplines. Students from fields such as applied sciences, computer science, sports science, accounting and other non-management disciplines may have limited prior exposure to entrepreneurship, financial management and digital business concepts.

In such circumstances, differences in students' prior knowledge may create disparities in classroom learning. Ledermuller and Fallmann (2017) indicate that students who have limited prior knowledge may require additional opportunities to review, repeat and apply course content. However, face-to-face classroom sessions are constrained by time and may not provide sufficient opportunities for every student to receive personalized explanations (Chen & Looi, 2007; Contrino et al., 2024; Wanner & Palmer, 2015).

A MOOC-based supplementary learning resource may provide a potential solution to this pedagogical challenge (Azami & Ibrahim, 2019). Through video materials, interactive notes, formative quizzes and self-paced learning activities, students may revisit difficult topics and obtain additional learning support outside the classroom. The incorporation of formative assessment may also enable students to monitor their own learning progress. Therefore, the study aims to examine whether students demonstrated improvement in conceptual understanding and academic performance following the integration of the MOOC. Specifically, the study evaluates changes in students' understanding of entrepreneurship-related concepts, changes in quiz achievement and students' satisfaction with the MOOC.

The study contributes to the literature in three ways. First, it provides empirical evidence from a Malaysian higher education context. Second, it focuses on students who do not necessarily possess prior academic knowledge in business and management. Third, it demonstrates how a curriculum-aligned MOOC can be integrated as a supplementary learning intervention within a conventional university course.

2. Literature Review

MOOC-Based Learning in Higher Education: MOOCs have become an increasingly visible component of digital learning in higher education (Alhazzani, 2020; Azami & Ibrahim, 2019; Williams, 2024). Their primary characteristics include online accessibility, structured learning content, multimedia resources and

opportunities for learner interaction and assessment. The flexibility offered by MOOCs enables students to access learning materials at different times and locations. This feature may be particularly beneficial for students who require additional time to process course content or who prefer to revisit learning materials independently (Berezi, 2025; Zuhairi et al., 2024). In the context of formal higher education, MOOCs can be integrated into existing courses as supplementary learning resources (Azami & Ibrahim, 2019). Such integration may allow students to benefit from the flexibility of online learning while retaining the instructional support provided through face-to-face teaching. The pedagogical value of a MOOC therefore depends on the relationship between technology, content and learning design. A well-designed MOOC may provide students with opportunities for repeated exposure, self-assessment and independent learning (Pilli & Admiraal, 2017; Zhu, 2024).

Blended Learning and Academic Performance: Blended learning combines face-to-face instruction with online learning resources and activities. The approach assumes that the strengths of physical and digital learning environments can complement one another. Face-to-face instruction provides direct interaction, explanation and feedback, while online learning can provide flexibility, accessibility and opportunities for self-paced engagement. A meta-analysis by Vo et al. (2017) found a positive effect of blended learning on academic performance in higher education. Their findings indicated that students in blended learning environments generally achieved better academic outcomes than students in traditional classroom settings. More recent evidence has further highlighted the relationship between blended learning, student engagement and learning outcomes. A systematic review by de Bruijn-Smolders and Prinsen (2024) found that blended learning interventions generally demonstrated moderate to high positive impacts on student engagement and learning outcomes. These findings suggest that digital learning may contribute to academic performance when students are meaningfully engaged with the learning environment.

Self-Directed and Self-Regulated Learning in Digital Environments: Digital learning environments provide students with greater control over their learning activities. Students can often determine when to access content, how long to spend on a topic and whether to repeat learning activities. These characteristics are closely associated with self-directed and self-regulated learning. Self-regulated learning involves students actively monitoring and managing their learning processes. In digital environments, this may involve setting learning goals, monitoring understanding, revisiting difficult materials and evaluating performance through formative assessments. Recent research has investigated the integration of self-regulated learning into digital learning platforms. Elmabaredy and Gencel (2024), for example, examined a digital platform designed to integrate self-regulated learning features and reported positive implications for student achievement and performance. Similarly, Dinh and Phuong (2024) examined the relationship between student characteristics, self-regulated learning strategies, satisfaction and academic performance in MOOCs. Their findings reinforce the importance of students' learning strategies in shaping the effectiveness of online learning experiences. Accordingly, the present study conceptualizes MOOC-based supplementary learning as a digital learning intervention that may support self-directed learning through flexible access, repeated engagement and formative assessment.

Digital Learning and Conceptual Understanding: Conceptual understanding represents an important learning outcome in higher education. Students are expected not only to recall information but also to understand relationships between concepts and apply knowledge in appropriate contexts (Elmabaredy & Gencel, 2024; Siregar, 2024). Digital learning resources may support conceptual understanding by presenting information through multiple formats. Video, visual materials, interactive content and formative quizzes may provide students with different ways to engage with complex information. Repeated access to learning materials may also support the consolidation of knowledge (Din & Phuong, 2024). Students who experience difficulty during classroom instruction can revisit the relevant content at a later time. Therefore, the use of MOOC-based supplementary learning may be particularly valuable when students have diverse levels of prior knowledge.

Digital Learning and Academic Performance: Academic performance is commonly used to evaluate the effectiveness of teaching and learning interventions (Panadero et al., 2023). It may be assessed through examinations, quizzes, assignments, course grades or other forms of academic assessment. The relationship between digital learning and academic performance may be explained through several mechanisms (Chen, 2025). First, online learning increases access to learning materials. Second, repeated engagement may support

knowledge retention. Third, formative quizzes may allow students to identify learning gaps. Fourth, flexible access may enable students to allocate additional time to difficult topics. The present study focuses on quiz achievement as one indicator of academic performance. Although quiz scores do not represent students' overall academic achievement, they provide a measurable indicator of learning performance within the course context.

Entrepreneurship Education and Digital Learning: Entrepreneurship education increasingly incorporates digital technologies. Modern entrepreneurship requires students to understand not only traditional business concepts but also digital platforms, online marketing, content creation, e-commerce and digital financial management (Primario et al., 2022). The integration of digital learning into entrepreneurship education may therefore provide students with opportunities to connect theoretical knowledge with practical business activities (Zeng et al., 2024). In the present study, students were required to apply their learning through an online business project. The project involved business idea development, digital content creation, social media management, sales management and preparation of business performance information. This practical component makes the course particularly appropriate for MOOC-based supplementary learning because students can refer to the digital learning materials while implementing practical business activities.

Self-Regulated Learning Theory: Self-Regulated Learning (SRL) Theory provides an appropriate theoretical foundation for explaining how MOOC-based supplementary learning may support students' learning processes and academic outcomes. Self-regulated learning refers to the active process through which learners plan, monitor, regulate, and evaluate their own learning. Rather than being passive recipients of information, self-regulated learners exercise greater control over their learning goals, strategies, behaviors, and learning progress (Zimmerman, 2002). SRL encompasses cognitive, metacognitive, behavioral, motivational, and affective dimensions of learning and has been widely applied to explain how learners manage their learning processes across different educational environments (Panadero et al., 2023).

Zimmerman's model conceptualizes self-regulated learning as a cyclical process involving three interrelated phases: forethought, performance, and self-reflection (Zimmerman, 2002; Panadero, 2017). The forethought phase involves processes that occur before learning, including task analysis, goal setting, strategic planning, and self-motivation. The performance phase occurs during learning and involves self-control and self-observation as learners implement learning strategies and monitor their progress. The self-reflection phase occurs following learning activities and involves evaluating one's performance and responding to the learning outcomes. The outcomes of self-reflection may subsequently influence students' planning and learning strategies in subsequent learning activities.

The characteristics of MOOC-based supplementary learning are particularly compatible with these self-regulatory processes. Digital learning environments provide learners with greater flexibility in determining when, where, and how they engage with learning materials. Such flexibility enables students to manage their learning pace, revisit difficult content, allocate additional time to areas in which they experience difficulty, and monitor their progress through formative learning activities. Previous research has highlighted the importance of self-regulated learning in digital learning environments and demonstrated that incorporating SRL-supportive features into digital platforms can contribute positively to students' achievement and performance (Elmabaredy & Gencel, 2024). Similarly, Dinh and Phuong (2024) emphasized the role of self-regulated learning strategies in shaping students' satisfaction and academic performance within MOOC environments.

In the context of the present study, the curriculum-aligned MOOC incorporated video lectures, interactive notes, infographics, formative quizzes, reinforcement activities, supplementary reading materials, and self-directed learning resources. These features provided opportunities for students to engage in learning behaviors consistent with the three phases of SRL. Flexible and self-paced access to learning materials may support the forethought phase by allowing students to organize and plan their learning activities. During the performance phase, students can revisit videos and learning materials, engage with formative activities, and monitor their understanding through quizzes. Formative assessment and repeated learning opportunities may subsequently support self-reflection by enabling students to evaluate their progress, identify gaps in their understanding, and adjust their subsequent learning strategies.

Accordingly, SRL Theory provides an explanatory mechanism linking the design of the MOOC-based

supplementary learning intervention with the learning outcomes examined in this study. The theoretical premise is that the educational value of the MOOC does not arise merely from providing additional online materials. Instead, its value may lie in providing an environment that enables students to exercise greater control over their learning, monitor their understanding, revisit learning materials, and evaluate their progress. These self-regulatory opportunities may subsequently contribute to stronger conceptual understanding and academic performance.

However, the present study does not directly measure students' level of self-regulated learning. Therefore, SRL Theory is employed as a theoretical lens to explain how the affordances of the MOOC may support learning rather than as an empirically tested mediating mechanism. The findings should consequently be interpreted as being consistent with SRL principles rather than as direct evidence that the intervention improved students' self-regulated learning capabilities.

3. Research Methodology

The unit of analysis is individual who are involved of 92 undergraduate students at a Malaysian higher education institution. The participants attended a blended learning environment that combined face-to-face instruction with a MOOC-based supplementary learning intervention. Data were collected from three sources: (1) pre- and post-intervention assessments of students' conceptual understanding, (2) quiz performance before and after the intervention, and (3) a student satisfaction survey.

This study employed a one-group pre-test–post-test design to evaluate changes in students' learning outcomes following the implementation of a curriculum-aligned MOOC-based supplementary learning intervention. The participants comprised 92 undergraduate non-business students enrolled in an entrepreneurship course at a Malaysian higher education institution. Purposive sampling was employed to select participants who met the specific criteria relevant to the study. The participants comprised undergraduate students from non-business academic backgrounds who were enrolled in the entrepreneurship course and participated in the MOOC-based supplementary learning intervention. This sampling technique was considered appropriate because the study aimed to evaluate the learning outcomes of a specific group of students who had direct exposure to the intervention, rather than to generalize the findings to the broader university student population. Data were collected at two measurement points, before and after the MOOC intervention, to examine changes in students' perceived conceptual understanding and quiz performance. Following the intervention, students' satisfaction and perceived benefits of the MOOC were also assessed.

The research procedure was conducted in several stages. First, eligible non-business undergraduate students enrolled in the entrepreneurship course were identified and briefed on the purpose and procedures of the study. Prior to the implementation of the MOOC-based supplementary learning intervention, a pre-intervention assessment was administered to establish students' baseline perceived conceptual understanding and quiz performance. Subsequently, students were provided access to the curriculum-aligned MOOC, which complemented the existing face-to-face classroom instruction. The MOOC incorporated video lectures, interactive notes, infographics, formative quizzes, reinforcement activities, supplementary reading materials, and self-directed learning resources. Students were given flexible access to these materials throughout the intervention period to support preparation, revision, and independent learning.

Upon completion of the intervention, a post-intervention assessment was administered to evaluate changes in students' perceived conceptual understanding and quiz performance. Students were also invited to complete a satisfaction and perception survey to evaluate their learning experience with the MOOC, including its accessibility, usefulness, ease of use, and support for self-paced learning. The pre- and post-intervention data were subsequently matched, coded, and analysed using IBM SPSS Statistics Version 30. Appropriate descriptive statistics were used to summarise changes in students' learning outcomes and their perceptions of the MOOC-based supplementary learning intervention.

Validity for Research Instrument

Content validity was established by mapping the assessment items to the relevant course learning outcomes and MOOC learning content. This alignment ensured that the instruments assessed the knowledge and

competencies specifically targeted by the intervention.

To establish content validity, the instruments were reviewed by two experts with relevant expertise in entrepreneurship education, digital learning, and/or educational assessment. The reviewers evaluated the relevance, clarity, and appropriateness of the items in relation to the study objectives and course learning outcomes. Revisions were made based on the feedback received prior to data collection.

4. Results

Pre-MOOC Learning Needs: Table 1 presents the students' reported learning needs prior to the implementation of the MOOC-based supplementary learning intervention. The findings indicate varying levels of prior understanding and confidence across the assessed learning areas. The lowest level of understanding was reported for basic financial management in a business context, with only 23.3% of students indicating that they understood the area, while 76.6% reported a lack of understanding. Similarly, only 16.5% of students expressed confidence in their ability to produce digital content, representing the lowest level of confidence among the assessed areas.

Students also reported limited understanding of the use of digital platforms to create business value, with only 34.9% indicating that they understood the concept. In comparison, understanding of basic course-related concepts was relatively higher at 43.2%, although more than half of the students (56.8%) still reported a lack of understanding.

Overall, the findings reveal substantial learning gaps before the implementation of the MOOC-based supplementary learning intervention. The most pronounced gaps were observed in students' confidence in producing digital content and their understanding of basic financial management in a business context. These findings suggest that students entered the course with varying levels of prior knowledge and required additional learning support to strengthen their understanding of the assessed concepts.

Table 1: Students' Pre-MOOC Learning Needs

Learning Area	Understanding (%)	Lack of Understanding (%)
Basic financial management in a business context	23.3%	76.6%
Basic course-related concepts	43.2%	56.8%
Use of digital platforms to create business value	34.9%	65.1%
Confidence in producing digital content	16.5%	83.5%

Changes in Conceptual Understanding: Table 2 presents the changes in students' reported understanding before and after the implementation of the MOOC-based supplementary learning intervention. The findings indicate substantial improvements across all four measured learning outcomes. Understanding of key course concepts increased from 43.8% before the intervention to 91.7% after the intervention, representing an increase of 47.9 percentage points. Similarly, students' understanding of the entrepreneur support system increased from 39.6% to 87.5%, representing an improvement of 47.9 percentage points.

Understanding of e-entrepreneurship concepts increased from 42.7% to 89.6%, reflecting a 46.9 percentage-point increase. The largest relative improvement was observed in students' understanding of basic financial management, which increased from 43.8% before the intervention to 88.5% after the intervention, representing a 44.7 percentage-point increase.

Overall, the findings demonstrate a substantial increase in the proportion of students reporting understanding across all assessed learning outcomes. The post-MOOC percentages ranged from 87.5% to 91.7%, compared with 39.6% to 43.8% before the intervention. The greatest percentage-point improvements were observed in understanding key course concepts and understanding of the entrepreneur support system, both increasing by 47.9 percentage points. Although understanding of basic financial management recorded the smallest percentage-point increase (44.7 percentage points), the post-MOOC understanding level still reached 88.5%, indicating a substantial improvement.

These findings suggest that the MOOC-based supplementary learning intervention was associated with improved perceived understanding of the assessed concepts. The improvement may reflect the contribution of structured digital learning materials, including multimedia content, interactive resources and supplementary learning activities, which provided students with additional opportunities to access and revisit the learning content.

Table 2: Changes in Students' Conceptual Understanding Before and After MOOC Implementation

Learning outcome	Pre-MOOC	Post-MOOC	Percentage-point change
Understanding of key course concepts	43.8%	91.7%	+47.9
Understanding of the entrepreneur support system	39.6%	87.5%	+47.9
Understanding of e-entrepreneurship concepts	42.7%	89.6%	+46.9
Understanding basic financial management	43.8%	88.5%	+44.7

Changes in Quiz Performance: Table 3 shows a substantial improvement in students' quiz achievement after the implementation of the MOOC. Before the MOOC implementation, only 15 students (15.7%) achieved a score of 80% and above. After participating in the MOOC, this number increased considerably to 65 students (67.7%), representing an increase of 52.0 percentage points (pp). This indicates that the number of high-achieving students increased by more than four times after the MOOC implementation. Similarly, the number of students who scored below 50% decreased from 14 students (14.6%) before the MOOC to none after the MOOC implementation (0.0%), representing a reduction of 14.6 percentage points. This indicates that the MOOC may have been useful for students who primarily demonstrated weaker performance to improve their quiz achievement. Overall, the findings indicate a positive change in students' achievement levels, with fewer students remaining in the low-achievement category and a significant increase in the number of students attaining high scores.

Table 3: Changes in Students' Quiz Achievement Before and After MOOC Implementation

Achievement category	Before MOOC	After MOOC	Absolute change
Score of 80% and above	15 students (15.7%)	65 students (67.7%)	+52.0 pp
Score below 50%	14 students (14.6%)	0 students (0.0%)	−14.6 pp

Students perceived benefits: The open-ended responses indicated generally positive perceptions towards the MOOC-based supplementary learning intervention (Table 4). The most frequently identified theme was the flexibility and accessibility of the MOOC, with 78 students (81.3%) highlighting the advantage of being able to access the learning materials at any time. This suggests that students value the flexibility provided by the MOOC, particularly in allowing them to learn according to their own pace and schedule. The second most frequently reported theme was the usefulness of learning videos in improving understanding, mentioned by 72 students (75.0%). Students' responses suggested that the videos helped to clarify concepts and supported their understanding of the subject matter. In addition, 65 students (67.7%) described the MOOC as easy to use and navigate, while 58 students (60.4%) indicated that the MOOC supported revision and self-paced learning. The results indicate that the MOOC was generally well-received by students, especially in terms of its accessibility, flexibility, multimedia learning materials, and usefulness for learning the course material.

Table 4: Students' Perceived Benefits of the MOOC

Perceived benefit	Percentage of students
Flexible and anytime access	81.3%
Learning videos improved understanding	75.0%
Easy to use and navigate	67.7%
Supports revision and self-paced earning	60.4%

Discussion

The present study examined the effectiveness of a curriculum-aligned MOOC-based supplementary learning intervention in supporting non-business undergraduate students enrolled in an entrepreneurship course. Overall, the findings demonstrate consistent improvements across three key learning outcomes, namely conceptual understanding, academic performance and students' perceptions towards digital learning. Although the study employed a one-group pre-post evaluation design and therefore does not establish causal relationships, the observed improvements suggest that the MOOC served as an effective supplementary learning resource within a blended learning environment.

The improvement observed in the present study is consistent with Vo et al. (2017), whose meta-analysis demonstrated a positive effect of blended learning on academic performance in higher education. Similarly, de Bruijn-Smolders and Prinsen (2024) reported moderate to high positive effects of blended learning interventions on student engagement and learning outcomes. The present study extends these findings by demonstrating similar positive learning patterns among non-business students enrolled in an entrepreneurship course, a context in which students may have limited prior exposure to business-related concepts.

The substantial improvement in students' conceptual understanding indicates that the MOOC successfully addressed the knowledge gaps identified before implementation. Before the intervention, many students reported limited understanding of entrepreneurship concepts, digital business, financial management and digital content creation. Following the implementation of the MOOC, the proportion of students reporting understanding increased markedly across all measured constructs. These findings support the argument that digital learning resources can reinforce conceptual learning by allowing students to revisit instructional materials repeatedly, learn at their own pace, and access multiple representations of knowledge through videos, infographics and interactive activities (Chen & Looi, 2007; Contrino et al., 2024; Wanner & Palmer, 2015). Such flexibility is particularly valuable for non-business students who may lack prior exposure to entrepreneurship-related concepts (Li et al., 2025).

The improvement in quiz performance further strengthens the educational value of the MOOC-based supplementary learning intervention. The substantial increase in the proportion of students achieving scores above 80%, together with the elimination of students scoring below 50%, suggests that additional digital learning opportunities may help narrow achievement gaps among learners with different levels of prior knowledge. Rather than replacing classroom instruction, the MOOC appeared to extend learning beyond scheduled contact hours by providing continuous access to revision materials and formative learning activities. This finding is consistent with blended learning literature, which suggests that integrating online learning with face-to-face instruction can enhance academic performance through greater engagement and more frequent interaction with learning resources (Vo et al., 2017; de Bruijn-Smolders & Prinsen, 2024).

In addition, the improvement in quiz performance supports previous evidence that integrating digital learning resources with conventional instruction can enhance academic achievement. Vo et al. (2017), for example, reported an overall positive effect of blended learning on student performance in higher education. More recently, Uygun and Cesur (2025) demonstrated positive effects of MOOC-supported instruction on learner achievement and satisfaction. While these studies were conducted in different educational contexts, the present findings provide additional evidence that MOOC-based supplementary learning may support academic performance, particularly among students studying outside their primary disciplinary background.

The positive perceptions reported by students further explain the observed learning improvements. Most participants highlighted the flexibility of accessing learning materials at any time, the usefulness of instructional videos, the ease of navigating the platform, and the support provided for revision. These findings are consistent with previous studies that identify accessibility, learner autonomy and multimedia learning as important characteristics contributing to effective MOOC implementation (Azami & Ibrahim, 2019; Dinh & Phuong, 2024). The ability to control learning pace enables students to revisit difficult concepts, thereby promoting deeper cognitive processing and reducing dependence on limited classroom time.

From a theoretical perspective, the findings align closely with self-regulated learning theory. The MOOC encouraged students to take greater responsibility for monitoring their own learning progress through flexible access, formative quizzes and repeated engagement with instructional materials. Such learning behaviors reflect important components of self-regulated learning, including planning, self-monitoring and self-evaluation. The present findings therefore support recent studies suggesting that digital learning environments become more effective when they facilitate learners' self-regulation rather than merely providing online content (Elmabaredy & Gencel, 2024; Dinh & Phuong, 2024).

The findings of the present study can be interpreted through the lens of Self-Regulated Learning Theory. Zimmerman (2002) conceptualizes self-regulated learning as a cyclical process involving forethought, performance, and self-reflection, through which students actively plan, monitor, and evaluate their learning. The design of the MOOC-based supplementary learning intervention provided several opportunities for students to engage in behaviors consistent with these processes.

The substantial improvements observed in students' perceived conceptual understanding and quiz performance may be partly explained by the flexibility and repeated learning opportunities provided by the MOOC. Students were able to access learning materials according to their own schedules, revisit difficult concepts, and use formative learning activities to monitor their understanding. These characteristics are consistent with the performance and self-reflection processes of SRL, in which learners monitor their progress, evaluate their performance, and modify their learning strategies accordingly (Zimmerman, 2002; Panadero, 2017).

The students' perceptions of the MOOC provide additional support for this interpretation. Flexible and anytime access was the most frequently reported benefit, while students also valued learning videos and the ability to use the MOOC for revision and self-paced learning. These findings suggest that students valued features that provided greater autonomy and control over their learning processes. This interpretation is consistent with previous research demonstrating the relevance of self-regulated learning in digital learning environments (Dinh & Phuong, 2024) and the potential of SRL-integrated digital platforms to support students' achievement and performance (Elmabaredy & Gencel, 2024).

Nevertheless, these findings should not be interpreted as direct evidence that the MOOC improved students' self-regulated learning. As SRL was not directly measured in the present study, the theory serves primarily as an explanatory framework for understanding how the learning affordances provided by the MOOC may have contributed to the observed outcomes. Future research could directly measure students' self-regulated learning behaviors and examine whether SRL mediates the relationship between engagement with MOOC-based supplementary learning and academic performance.

An important contribution of this study lies in its educational context. Much of the existing MOOC literature focuses on fully online courses or programs involving students from technology or business disciplines (e.g., Huang et al., 2022; Le & Ho, 2026; Shang et al., 2024; Uygun & Cesur, 2025). In contrast, this study demonstrates that curriculum-aligned MOOC-based supplementary learning can effectively support students from diverse non-business academic backgrounds who are required to study entrepreneurship as a compulsory university course. This finding extends current knowledge by illustrating that digital learning interventions may be particularly beneficial for heterogeneous student populations possessing different levels of prior knowledge and learning readiness.

While previous studies have established the benefits of MOOCs and blended learning across various higher education contexts, the present study extends this evidence to non-business students undertaking entrepreneurship education. This distinction is important because these students may enter the course with limited prior exposure to entrepreneurship, financial management and digital business concepts. The substantial improvements observed following the intervention therefore suggest that curriculum-aligned MOOC resources may be particularly useful as supplementary learning support for academically heterogeneous student populations.

5. Limitations and Suggestions for Future Research

Despite the positive findings, several limitations should be considered when interpreting the results. First, the study employed a one-group pre-test–post-test design without a control or comparison group. Therefore, although improvements were observed following the implementation of the MOOC-based supplementary learning intervention, the changes cannot be attributed exclusively to the MOOC. Other factors, including face-to-face instruction, students' continued exposure to the course content, maturation, and repeated assessment, may have contributed to the observed improvements. Future studies should employ experimental or quasi-experimental designs involving appropriate comparison groups to provide stronger evidence regarding the effectiveness of MOOC-based supplementary learning.

Second, the study was conducted at a single Malaysian higher education institution and focused on non-business undergraduate students enrolled in one entrepreneurship course. These contextual characteristics may limit the generalisability of the findings to other institutions, academic disciplines, courses, and student populations. Future research should therefore involve larger and more diverse samples across multiple institutions and disciplines. Comparative studies involving students with different academic backgrounds may also provide insights into whether prior disciplinary knowledge influences the effectiveness of MOOC-based supplementary learning.

Third, some of the learning outcomes were based on students' self-reported perceptions of their conceptual understanding. Although such measures provide useful information about students' perceived learning progress, they may not fully reflect actual knowledge acquisition. Future studies should incorporate validated objective assessments alongside self-reported measures to provide a more comprehensive evaluation of learning outcomes.

Fourth, the present study primarily relied on descriptive statistics to evaluate changes in students' learning outcomes. While the observed percentage changes indicate positive patterns following the intervention, future studies should employ appropriate inferential statistical analyses and report effect sizes to determine the statistical significance and magnitude of the observed changes.

Fifth, the study focused primarily on learning outcomes measured within the intervention period and did not examine whether the observed improvements were sustained over time. Future longitudinal research could incorporate delayed post-intervention assessments to determine whether MOOC-supported learning contributes to longer-term knowledge retention and application.

Finally, the study evaluated the MOOC as an overall supplementary learning intervention without examining students' actual engagement with individual MOOC components. Future research could incorporate learning analytics, including frequency of access, time spent on learning materials, video engagement, formative quiz attempts, and module completion. Such data could be used to examine the relationship between patterns of MOOC engagement and academic outcomes and to identify which specific features of the MOOC contribute most strongly to student learning.

Conclusion

This study demonstrates that a curriculum-aligned MOOC-based supplementary learning intervention has considerable potential to enhance learning outcomes among non-business undergraduate students enrolled in an entrepreneurship course. Following the implementation of the MOOC, students reported higher levels of conceptual understanding, achieved better quiz performance, and expressed positive perceptions regarding the flexibility, accessibility and usefulness of the digital learning resources.

The findings suggest that the effectiveness of the intervention was not merely attributable to the availability of online materials but to the purposeful integration of the MOOC within the existing curriculum. By complementing face-to-face instruction with structured multimedia resources, formative assessments and self-paced learning opportunities, the MOOC provided continuous academic support beyond conventional classroom teaching.

From a practical perspective, the findings offer valuable implications for higher education institutions seeking to strengthen digital transformation initiatives. Curriculum-aligned MOOCs can function as scalable supplementary learning resources capable of supporting students with diverse educational backgrounds while promoting independent learning and greater engagement with course content. Such approaches are particularly relevant for entrepreneurship education, where students are expected to integrate conceptual knowledge with practical digital business skills.

Overall, the study contributes to the growing body of literature on blended learning by providing empirical evidence that MOOC-based supplementary learning can enhance students' conceptual understanding, academic achievement and learning experience within a Malaysian higher education context. Future research involving larger samples, multiple institutions and more rigorous experimental designs is recommended to further validate these findings and identify the specific MOOC features that contribute most significantly to student success.

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A Bibliometric Analysis on the Nexus of Financial Literacy and Cashless Payment Adoption

*Nurul Syazwani Mohd Noor, Juliana Arifin, Farah Amalina Md Nawi, Norhidayah Abu Bakar
Faculty of Business and Management, Universiti Sultan Zainal Abidin, Terengganu, Malaysia
Email: *syazwanimnoor@unisza.edu.my, julianaarifin@unisza.edu.my, farahamalina@unisza.edu.my, hidayahabubakar@unisza.edu.my
Corresponding Author: Nurul Syazwani Mohd Noor

Abstract: Over the past decade, scholarly interest in the nexus between financial literacy and cashless payments has grown significantly. paving the way for future research to explore new dimensions within this field. This study scientifically analyses and reviews the existing literature on financial literacy and cashless payments using a bibliometric analysis approach. Intellectual and logical structuring was carried out using VOSviewer by performing an analysis of 713 papers published from 2000 to 2024 in the Web of Science (WoS) database. The construction of network maps using co-authorship and co-occurrence analysis revealed interesting patterns and themes in the field of financial literacy and cashless payments. The discussion helps to identify the nature and scope of research conducted in both domains since their inception. This reflection provides recommendations and guidance grounded in prior studies, offering a clear direction for future research on financial literacy and cashless payment adoption, while also considering potential challenges and limitations.

Keywords: *Financial literacy, cashless payments, bibliometric analysis, Web of Science*

1. Introduction

The global shift towards cashless payment systems has been driven by advancements in financial technologies (FinTech), whose implementation aims to enhance transaction efficiency, convenience, and transparency. The rapid progress of FinTech in recent decades has increasingly transformed consumer preferences (Bhattacharjee et al., 2024) and helped them access financial services and markets much better than before (Kou et al., 2021). While these significant changes have increased the number of financial products, consumers still face various difficulties and complexities when using them (Long et al., 2023). For example, cashless payment systems, which are one of the components of FinTech, encompassing mobile payment, e-wallets, electronic bank transfers, QR codes, and contactless cards, offer benefits such as transaction efficiency, enhanced security, and financial inclusion (Vania et al., 2024). However, the adoption of these systems is contingent on users' level of financial literacy, which includes the knowledge and skills required to make informed financial decisions (Shehadeh et al., 2024b).

In both theory and practice, it is essential to acknowledge and comprehend the impact of financial literacy on the development of cashless payment systems (Świecka, 2018). Financial literacy emerges as a pivotal factor influencing individuals' ability to navigate and adopt digital systems effectively. While cashless payment adoption offers significant benefits, including economic inclusivity and reduced transaction costs, the lack of financial literacy often impedes its widespread acceptance (Yang et al., 2023; Shehadeh et al., 2024a). In general, financial literacy can be defined as the ability to understand and apply effective financial management skills, and it is widely believed that this concept should be instilled from an early age. It is commonly defined as the ability to effectively manage personal finances, including saving, investing, and handling debt. In 2022, the Organisation for Economic Co-operation and Development (OECD) proposed a comprehensive framework for measuring financial literacy, encompassing an individual's knowledge, attitudes, behaviours, skills, and awareness. As the global economy enters a stagnation phase and a recession increases in the post–COVID-19 era, the level of financial literacy among society has become increasingly important to ensure the right decisions are made for their financial well-being. This ability directly affects individuals' quality of life, hence making financial literacy a key to sustainable development highlighted in the United Nations' 2030 Agenda in 2015 (Świecka et al., 2020; Świecka et al., 2021).

In that regard, this study tends to examine and shed further light on the academic discourse around financial literacy and cashless payment adoption. Against this background, this study attempts to provide preliminary ideas in the field of financial literacy and its role in a cashless society. This study is critical because the rapid

changes in the digital financial system require tremendous support from society in terms of knowledge, skills, and the ability to adapt to technologies. Meanwhile, financial literacy may also influence the adoption and usage of cashless payment services (Long et al., 2023). This study aims to identify knowledge gaps through bibliographic coupling, thereby offering a roadmap for future research that may contribute to the advancement of a cashless society through enhanced financial literacy.

Following this brief introduction, the paper is structured as follows. The following section presents a literature review and insights into financial literacy and cashless payment adoption. The third section outlines the methodology employed in this study, including the data collection process and the scope of the research. The fourth section discusses the bibliometric findings and provides a critical analysis of the identified themes through bibliographic coupling and content analysis. Finally, the fifth and sixth sections conclude the study by outlining its limitations and offering suggestions for future research directions.

2. Literature Review

A review of research conducted between 2000 and 2010 highlighted that studying financial literacy is a significant challenge due to the absence of a well-defined and universally accepted definition in the literature (Remund, 2010). Ever since, researchers have believed that financial literacy has been portrayed as having a similar meaning to financial knowledge (Hilgert et al., 2003; Lusardi & Mitchell, 2011; Bucher-Koenen et al., 2016). Even though some studies commonly relate the concept of financial literacy to financial knowledge, it essentially has a more general definition comprising knowledge, behaviour, and attitudes of the people. According to the Organisation for Economic Co-operation and Development (OECD, 2020), financial literacy encompasses an integrated set of cognitive and behavioural capacities including awareness, knowledge, skills, and attitudes that collectively enable individuals to make informed financial decisions and pursue long-term financial well-being. Further, three main components of financial literacy are commonly identified as: (i) the individual's level of financial knowledge (cognitive aspect); (ii) attitudes towards saving; and (iii) financial behaviours (OECD, 2022).

When considered together, these elements play a crucial role in enabling the adoption of financial technology and digitalisation. Given the unique barriers to technology adoption experienced by the public, such as lack of knowledge, skills, and exposure, financial literacy becomes the best way to solve the issue. In a broader sense, cashless payments associated with technology usage and application are part of the development of FinTech. Not specific to cashless payments, FinTech adoption as a whole actually requires a high level of financial literacy (Yoshino et al., 2017). This is demonstrated by the positive association between financial literacy and FinTech adoption in Japan. To support the solution, policies are needed to improve financial literacy, including digital financial education programmes employed in schools and workplaces. These efforts are crucial because financial education indirectly influences FinTech adoption and usage by enhancing financial literacy. This is consistent with the findings of Henry et al. (2017), who analysed the 2017 Methods-of-Payment Survey in Canada and discovered that individuals with higher financial literacy, as measured by a standard assessment, tended to carry less cash and use cashless payment methods more frequently. Without financial literacy, individuals are generally less inclined to manage their finances through FinTech, i.e., cashless services (Bakar et al., 2020).

A study of Poland conducted by Świecka in 2018 portrayed that consumer knowledge of payment methods and their relationship with financial behaviour had long attracted the attention of researchers. However, no in-depth and empirically based scientific research had been completed in recent years. This might be due to the moderate digital literacy and necessary practices at that time. Nevertheless, Świecka (2018) demonstrated that individuals with higher levels of financial knowledge and skills tended to use cashless payment methods. This finding indicates that financial literacy is one of the key factors influencing the adoption of cashless payments. It is understood as both effective and easily understandable across diverse financial contexts, empowering individuals to actively engage in economic life. The COVID-19 pandemic has led to more emerging studies on the nexus between financial literacy and cashless payment adoption. While the pandemic has restricted outdoor activities, the implementation of contactless transactions has encouraged society to adopt cashless payments more widely.

Numerous studies have come out with significant findings on financial literacy and cashless payment adoption since then. Chih-Feng and Chun-Da (2020) suggest that individuals with higher financial literacy use mobile payment services more frequently as a preferred cashless method. Furthermore, individuals who prefer digital service providers tend to consider themselves more financially knowledgeable and generally more risk-tolerant (Königsheim et al., 2017; Mai, 2022). A higher level of financial knowledge can lead to more rational financial decisions, including responsible spending, effective money management, financial stability, and overall well-being (Swiecka et al., 2021). The introduction of new non-cash payment solutions, such as digital payments, can exclude older adults or individuals with limited financial knowledge, highlighting the importance of financial literacy related to payment systems. Additionally, a cashless society may face challenges in rural areas, where reliance on cash remains high and financial literacy levels tend to be lower compared to urban populations (Rahman et al., 2023). Studies among rural citizens or different income groups produce different results. In China, the 2015 and 2017 data from the China Household Finance Surveys showed that financial literacy plays a crucial role in enhancing the adoption of digital financial services, such as mobile payments, online borrowing, and online financial products. The influence is particularly stronger for online borrowing and financial products compared to mobile payments, indicating that the importance of financial literacy grows as the complexity of the digital financial service increases (Yang et al., 2023).

In addition, Seldal and Nyhus (2022) demonstrate that early adopters of new financial payment technologies tend to exhibit higher levels of financial literacy and typically come from younger age groups. The so-called Gen-Z is considered to have complex financial knowledge ranging from basic to advanced levels, with social influence having a positive effect on the intention to use cashless payments in Medan city, Indonesia (Pakpahan, 2024). This aligns with the evidence in the Asia–Pacific region, where 33% of Gen-Z spend over 6 hours daily on their mobile phones, with social media usage surpassing that of previous generations. The study also highlights that Gen-Z in Indonesia exhibits the highest mobile phone usage among all groups, averaging 8.5 hours per day. Growing up in the digital era has made Gen-Z highly attuned to technology, significantly influencing how they engage with the world and their approach to financial management (Vania et al., 2024).

Overall, this study examines how financial literacy in different dimensions affects cashless payment adoption. It is believed that there are some other factors that can be considered in influencing people's adoption of cashless payments. Over time, the field of financial technology, i.e., cashless payments and financial literacy, has developed into an interdisciplinary one. In light of this transformation, it is crucial to examine the available literature to identify how this research field is advancing. Therefore, this study uses bibliometric analysis tools to analyse important tendencies in the conceptual, intellectual, and social structure of the fragmented work. The following research questions (RQ) are the focus of this bibliometric study.
RQ1: What are the publication trends, and most prominent areas involved in the research on financial literacy and cashless payment adoption?
RQ2: Which countries are the major contributors to research on financial literacy and cashless payment adoption?
RQ3: What are the probable future areas of research on financial literacy and cashless payment adoption?

3. Methodology

Data Extraction, Inclusion and Exclusion Criteria

This study was conducted using bibliographic metadata. The methodology for this study began with identifying the appropriate database, followed by data collection guided by a defined search strategy. This study used all accessible metadata of the documents such as journal articles, early access, conference proceedings, books, or book chapters, and article reviews. In the first step, data were retrieved from the Web of Science (WoS) database on July 22, 2024. The majority of studies prefer the WoS database for bibliometric analysis because it includes highly reputable journals across multiple disciplines while excluding papers from magazines and non-scientific sources (Rodriguez-Ruiz et al., 2019; Khan et al., 2022), thereby ensuring the highest standards of thoroughness and quality (Ghosh, 2024). In fact, the WoS has long been recognised as the most comprehensive global citation database (Birkle et al., 2020; Öztürk et al., 2024) and its Journal Citation Reports (JCR) are widely regarded by the research community as a standard measure of journal impact (Liu et al., 2013; Carvalho et al., 2017; Rialti et al., 2019). In addition, WoS was selected as the sole database due to its standardised metadata, comprehensive citation records, and consistent indexing across disciplines, which are essential for reliable

bibliometric analysis (Linnenluecke et al., 2020; Ghosh, 2024). Despite this preference, the authors acknowledge that cross-database validation in future studies could broaden the scope of the findings.

The extracted documents from this database source were analysed using bibliometric techniques to develop the intellectual and conceptual structure that helps the study derive the connotations using co-word, co-citation, and co-author analysis (Linnenluecke et al., 2020). The different bibliometric indices can be used to derive the published document's research influence, for example, citation counts per paper, author and institution, and country (Haustein, S. & Larivière, 2015; Linnenluecke et al., 2020). However, this study focuses on understanding the knowledge structure using a co-word analysis of keywords. Therefore, the search was limited to the specific terms of keywords that appear in the title, abstract, and author's keywords. The search string is as follows: (("financial literac*") OR ("financial behavio*") OR ("financial attitude") OR ("financial knowledge") OR ("financial education") OR ("financial management")) AND ("cashless" OR "e-payment" OR ("digital payment") OR ("electronic payment") OR ("cashless payment") OR ("online payment") OR "e-wallets"). A total of 963 articles emerged after applying the given criteria. Although the search string was designed to capture core concepts related to financial literacy and digital payment systems, it is acknowledged that alternative terminologies including 'FinTech adoption,' 'contactless payment,' and 'digital finance' were not explicitly incorporated. This represents a boundary condition of the current study and should be considered when interpreting the findings. The second step involved filtering and screening the data. The subject included all categories with limited types of documents, excluding letters, books, meeting abstracts, news items, and notes. The search aimed at documents published between 2000 and 2024 to cover the research trends. After rigorous screening, 713 articles were considered for inclusion in the bibliometric analysis.

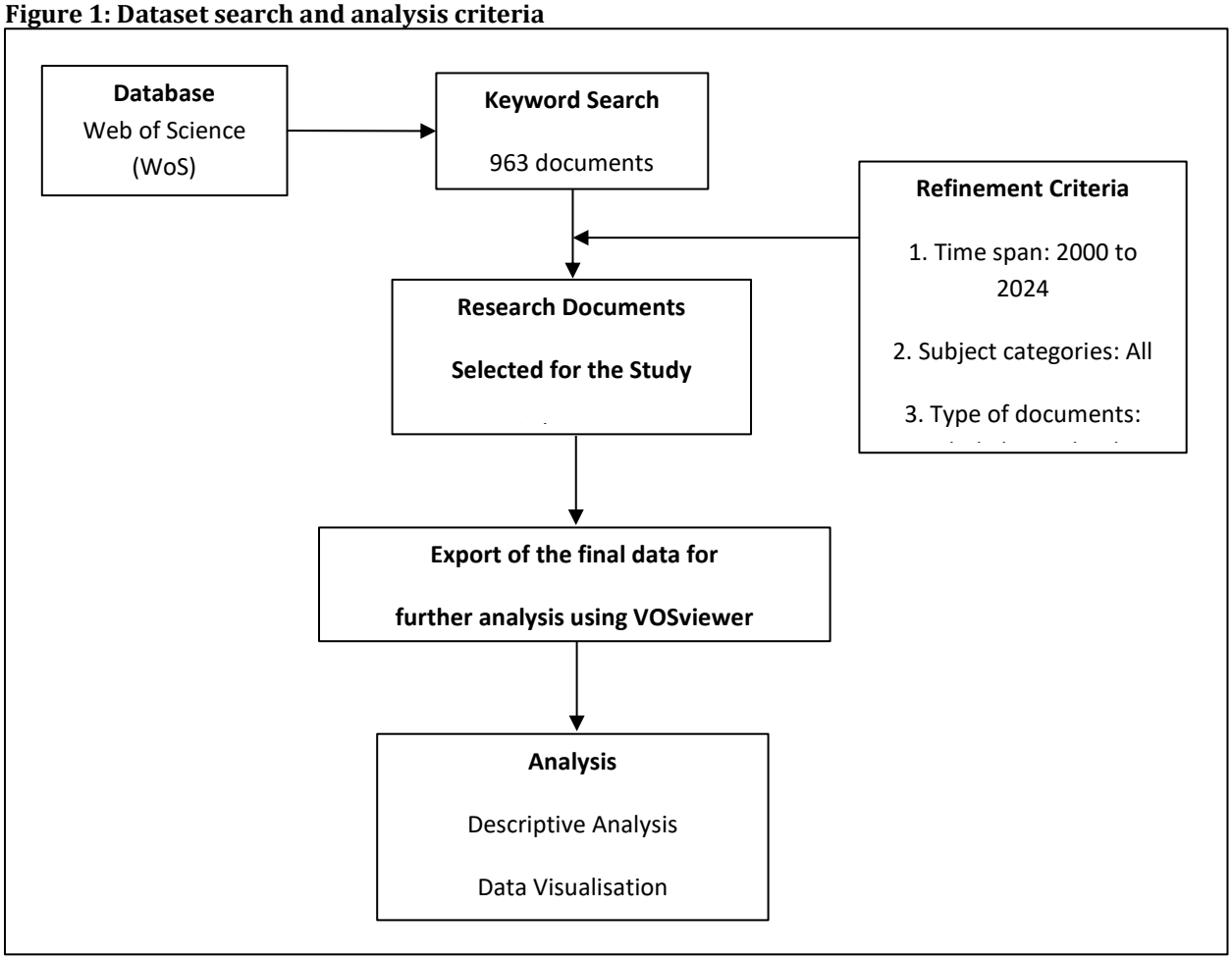
Data Analysis

The final step involved conducting a bibliometric analysis using VOSviewer software, which facilitates the essential task of bibliometric mapping. This software generates the interlinkages between the keywords, understanding the key research areas of the published articles based on the concept of the conjunction and concurrence of keywords (Zhu & Zhang, 2020; Ghosh, 2024). In the bibliometric section, this study analysed key information such as publication trends, document types, and country collaboration patterns. VOSviewer software was employed to perform network clustering through keyword analysis and bibliographic coupling (Eck & Waltman, 2010). Using bibliographic coupling, the study conducted a content analysis to identify major themes and suggest directions for future research on financial literacy and cashless payment adoption.

Following data extraction, a systematic screening process was undertaken. First, duplicate records were identified and removed automatically during the export process from WoS, as the database does not permit duplicate entries within a single search query. Records were then manually screened for relevance by reviewing titles, abstracts, and author keywords. Documents were excluded if they: (i) fell outside the defined document types (i.e., letters, books, meeting abstracts, news items, and notes); (ii) were unrelated to financial literacy or cashless/digital payment systems based on abstract screening; or (iii) lacked sufficient metadata for bibliometric analysis (e.g., missing author affiliations or keywords).

For the VOSviewer analysis, a minimum threshold of five occurrences was applied for keyword co-occurrence analysis to ensure only sufficiently represented terms were included in the network map. For co-authorship analysis, a minimum of two documents per author was set. These threshold values are consistent with conventions in bibliometric studies of comparable scope (Eck & Waltman, 2010; Linnenluecke et al., 2020). The resulting network maps were generated using both network visualisation and density visualisation modes to provide a comprehensive view of keyword relationships and thematic clusters. Figure 1 outlines the search criteria, including keywords, inclusion, and exclusion parameters, along with the subsequent analytical process.

Figure 1: Dataset search and analysis criteria



4. Results and Discussion

Document Types

In selecting the articles for review, this study included articles published in peer-reviewed journals and available in all languages. This study excluded articles published as letters, book chapters, meeting abstracts, news items, and notes. Further, articles that were not available as full-text articles and were outside the scope of the present study were omitted. Table 1 provides a synoptic overview of the selection criteria for the inclusion of document types undertaken by researchers for the selection of relevant studies. The criteria included produced 713 total of document types for further analysis.

Table 1: Inclusion of Document Types

No.	Document Types	Number of Articles
1.	Journal article	509
2.	Proceedings paper	117
3.	Early access	28
4.	Book chapter	21
5.	Editorial Material	11
6.	Book Review	15
7.	Review Article	12
	Total	**713**

Publication Trends

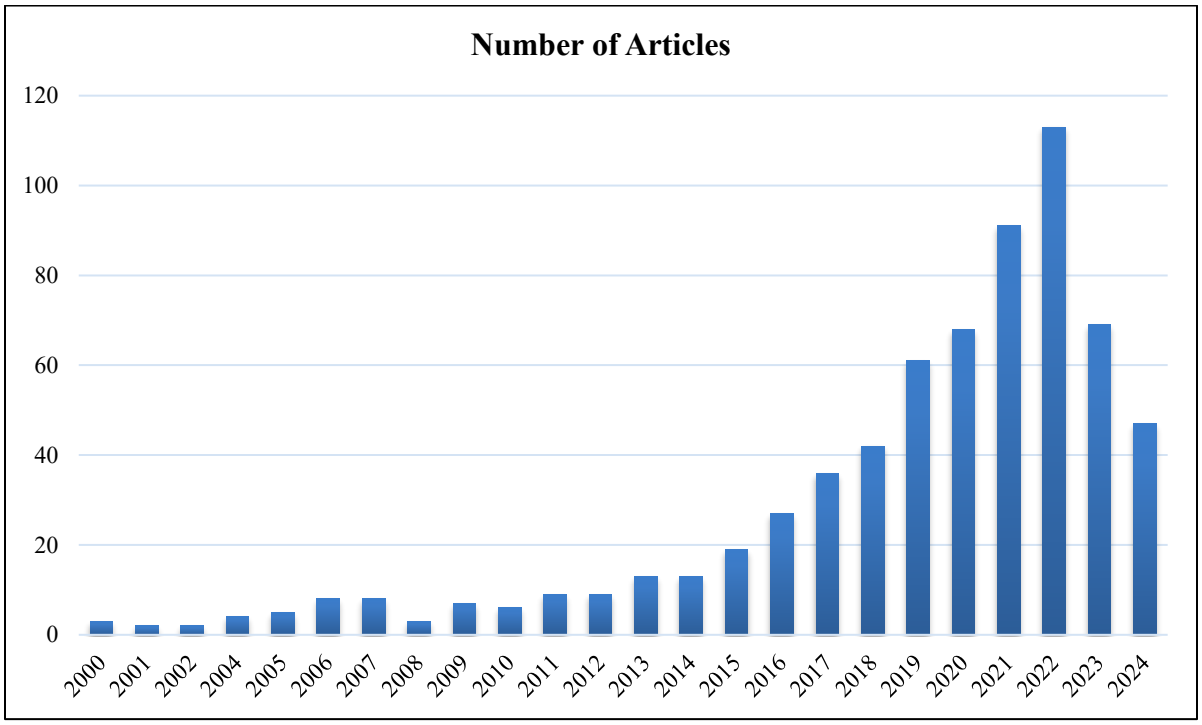
Figure 2 illustrates the publication trend within the dataset, highlighting a noticeable upward trajectory in recent years. From 2000 to 2005, the field gained minimal academic attention, with only a few articles published. Between 2006 and 2012, publications fluctuated without a clear growth pattern. A significant shift occurred in 2013, marked by the release of 13 articles, indicating a growing interest in the topic. Following this point, research output on financial literacy and cashless payment adoption expanded steadily, culminating in a peak in 2022 with 113 published articles. This sustained growth over the decade from 2013 to 2022 reflects increased scholarly focus, likely driven by global digitalisation trends, the rise of fintech, and greater awareness of financial inclusion issues.

First, the stream of publications indicates the increased awareness of financial literacy's importance. The growing recognition of the critical role of financial literacy in today's world underscores its importance for both individual financial well-being and overall economic stability. This awareness has led to a proliferation of research exploring various aspects of financial literacy, including its determinants, outcomes, as well as its relationship with other variables (Rehman & Mia, 2024). Second, the global shift towards cashless economies has led to the movement towards cashless transactions using various platforms such as mobile payments, digital wallets, and contactless transactions. These financial behaviours transformation prompting researchers to explore its factors and implications (Raya & Vargas, 2022). Third, the impact of COVID-19 has accelerated the adoption of cashless payments due to health concerns associated with physical cash. Additionally, the higher demand for cashless transactions during the pandemic contributes to rapid technological advancements. More new financial products and services have been introduced, necessitating a deeper understanding of financial literacy to navigate these innovations effectively. This has led to a surge in research focusing on the intersection of FinTech and financial literacy (Raj et al., 2024; Rehman & Mia, 2024). Lastly, the policy initiatives and financial inclusion efforts implemented by the governments and financial institutions, particularly in rural and underserved areas, have prompted studies examining the effectiveness of financial literacy programmes and the adoption of cashless payment systems among diverse populations (Khuc et al., 2022).

Studies in the two years after the peak year may have looked at the environmental impacts of cashless systems rather than the adoption process itself. Otherwise, the declining trend may be due to the researchers exploring other emerging variables associated with financial literacy and cashless payments. In sum, the upward trajectory of articles published in this collection over the years is a testament to the growing recognition of the significance of financial literacy and cashless payment adoption, underpinned by several factors such as awareness, policy initiatives, research advancements, and demand for evidence-based solutions.

In a theoretical context, the notable surge in publications post-2013, and particularly after 2020, aligns with the Technology Acceptance Model (TAM) and the Diffusion of Innovations Theory perspectives, which predict that the adoption of new technologies accelerates once a critical mass of users is reached (Rogers, 1983; Davis, 1989). The COVID-19 pandemic functioned as an exogenous shock that compressed adoption timelines, effectively advancing the cashless payment adoption curve by several years (Kotkowski & Polasik, 2021). This mirrors historical patterns observed during previous economic disruptions, where crisis conditions catalysed financial behaviour change.

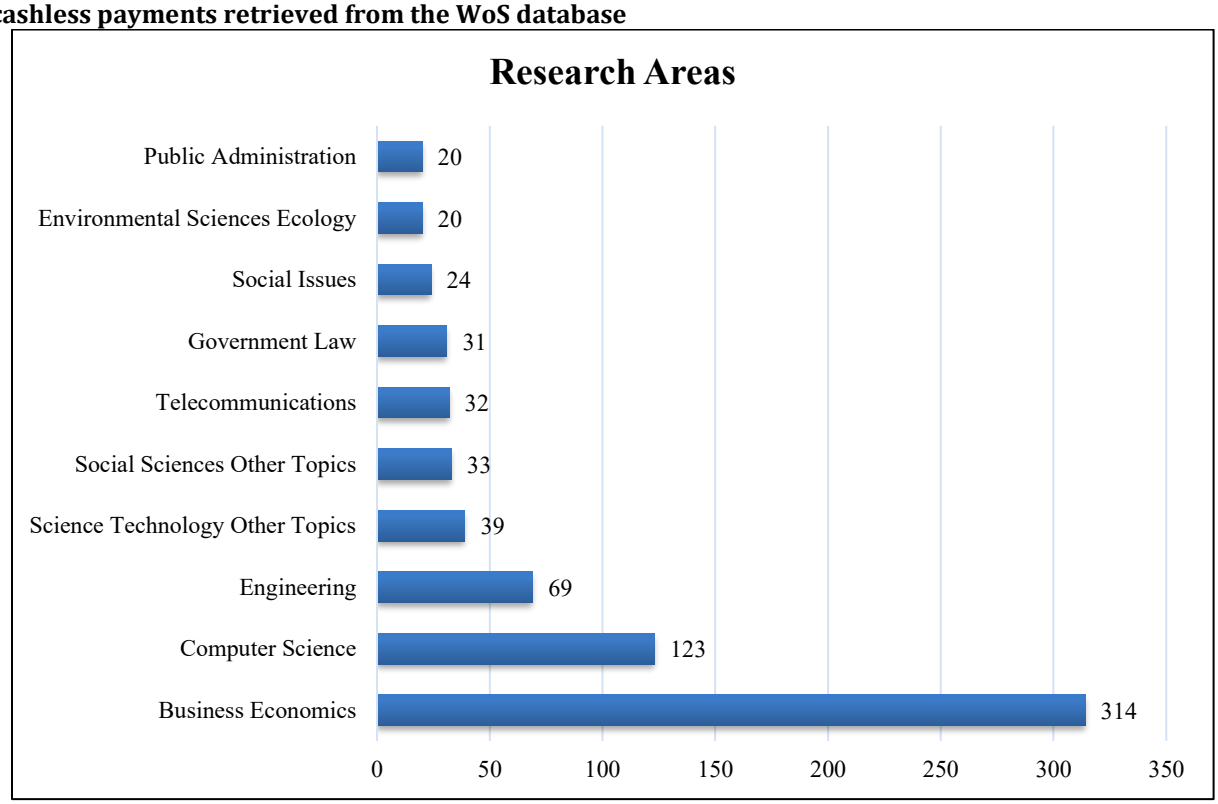
Figure 2: Annual publication trend of 713 papers for the period of 2000–2024 retrieved from WoS Database



Most Relevant Sources based on Research Areas

Figure 3 illustrates the publication trends of the most prominent sources contributing to the literature on financial literacy and cashless payments. The leading disciplines represented include business economics, computer science, and engineering. Among these, business economics stands out with the highest volume of publications (314 articles), followed by computer science with 123 publications during the review period. These subject areas are well-represented in scholarly publishing, reflecting a growing academic focus on the business and technological dimensions of financial literacy and digital payment systems. This surge can be linked to the rising relevance of these topics in the broader context of financial technology (FinTech). Moreover, the convergence of finance and technology is attracting increasing attention from academics, researchers, policymakers, and industry practitioners. The engineering field also contributes significantly, particularly through research on technological innovations, systems architecture, and implementation methodologies. Engineering is a key field in supporting financial literacy and digital payment adoption through the development of secure transaction platforms, encryption technologies, and robust infrastructure designed to mitigate cybersecurity threats. A deeper examination reveals that other contributing research areas include science and technology studies, social sciences, telecommunications, law and public policy, environmental science, and public administration. The growing volume of publications in these domains demonstrates a shift towards an interdisciplinary exploration of how digital transformation intersects with financial behaviour and literacy. Recent scholarship increasingly focuses on the integration of technology with financial knowledge, attitudes, and behaviours, particularly in the context of adopting cashless payment systems. These studies are published in highly regarded journals by leading academic publishers such as Springer, Elsevier, Wiley-Blackwell, Routledge and Cambridge University Press. These publishers are known for their high standards of peer review and scholarly rigor, thus further reinforcing the academic credibility, relevance, and impact of the work addressing the intersection of financial literacy and cashless payment adoption.

Figure 3: Top 10 research areas with a minimum of 20 published articles on financial literacy and cashless payments retrieved from the WoS database



Most Relevant Sources based on Countries (provided Country Collaboration Map)

Figure 4 presents the top 10 countries according to the most relevant publication sources in the research area. India became the most impactful country that published in the research area of financial literacy and cashless payments with 143 articles, followed by the USA (97), Australia (54), England (48), Malaysia (45), and Indonesia (34). The highest total number of publications originating from developing countries reflects the need for financial literacy and technological progress made in the nation and the interest in digital tools to boost the resilience of the cashless society. The figure also shows that African countries do not appear in the ranking. The bottom four countries among the top tier, with fewer than 30 publications in this research area are Japan (28), Republic of China (25), Poland (24) and Russia (23). These lower numbers of publications in the area may be contributed to by several factors. Russia and Poland, for instance, with varying economic conditions and geopolitical challenges, may allocate fewer resources to research areas that are not seen as immediate national priorities. Meanwhile, countries like Japan and China might already have well-established cashless payment systems and high levels of financial literacy, leading to less need for extensive research in these areas.

Theoretically, India's dominance in publication output is consistent with the diffusion of innovation framework, where developing economies with large unbanked populations represent high-stakes adoption environments that attract research attention (Ozili, 2020). India's demonetisation policy in 2016 and subsequent digital payment infrastructure initiatives (e.g., UPI) created a natural experiment environment, driving academic inquiry into adoption barriers, financial literacy gaps, and inclusion outcomes. The relatively lower output from Japan and China, by contrast, may reflect a research saturation effect where mature cashless ecosystems reduce the novelty value of adoption studies, shifting research focus towards optimisation and user behavior.

Figure 4: Top 10 most impactful countries with a minimum of 20 published articles on financial literacy and cashless payments retrieved from the WoS database

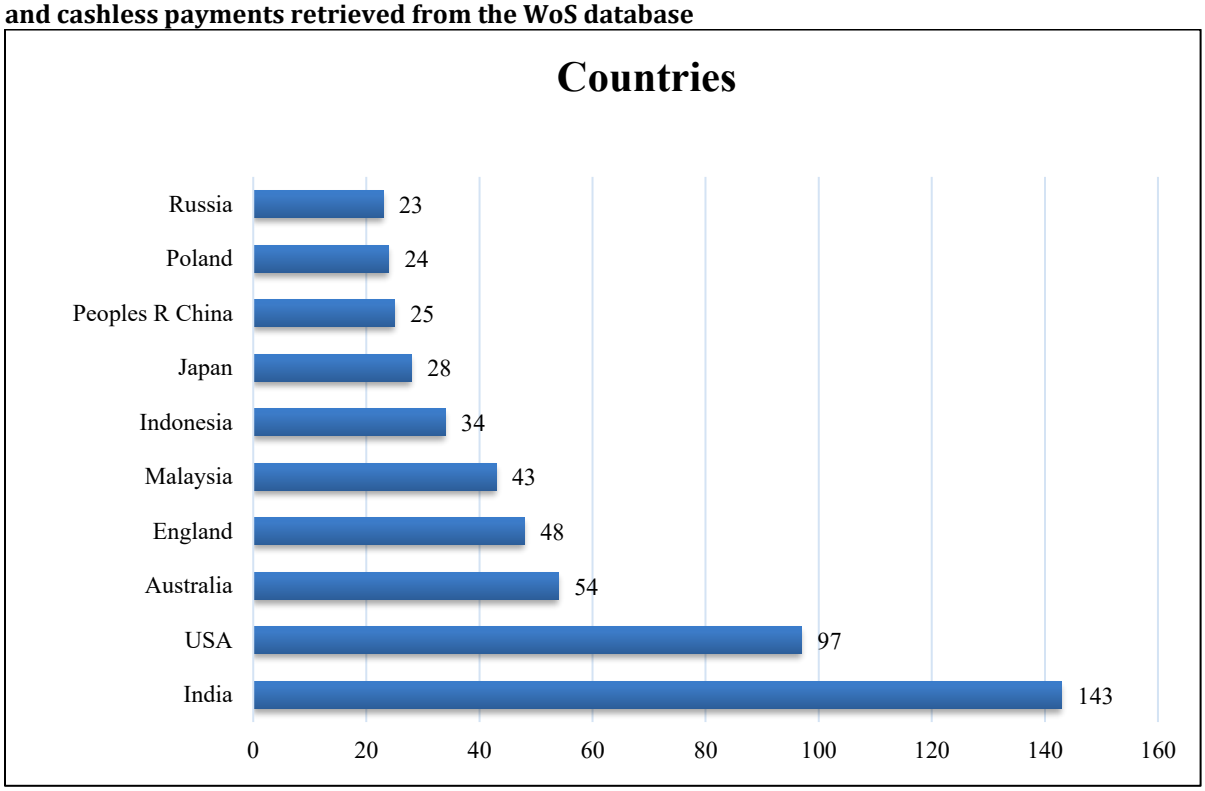
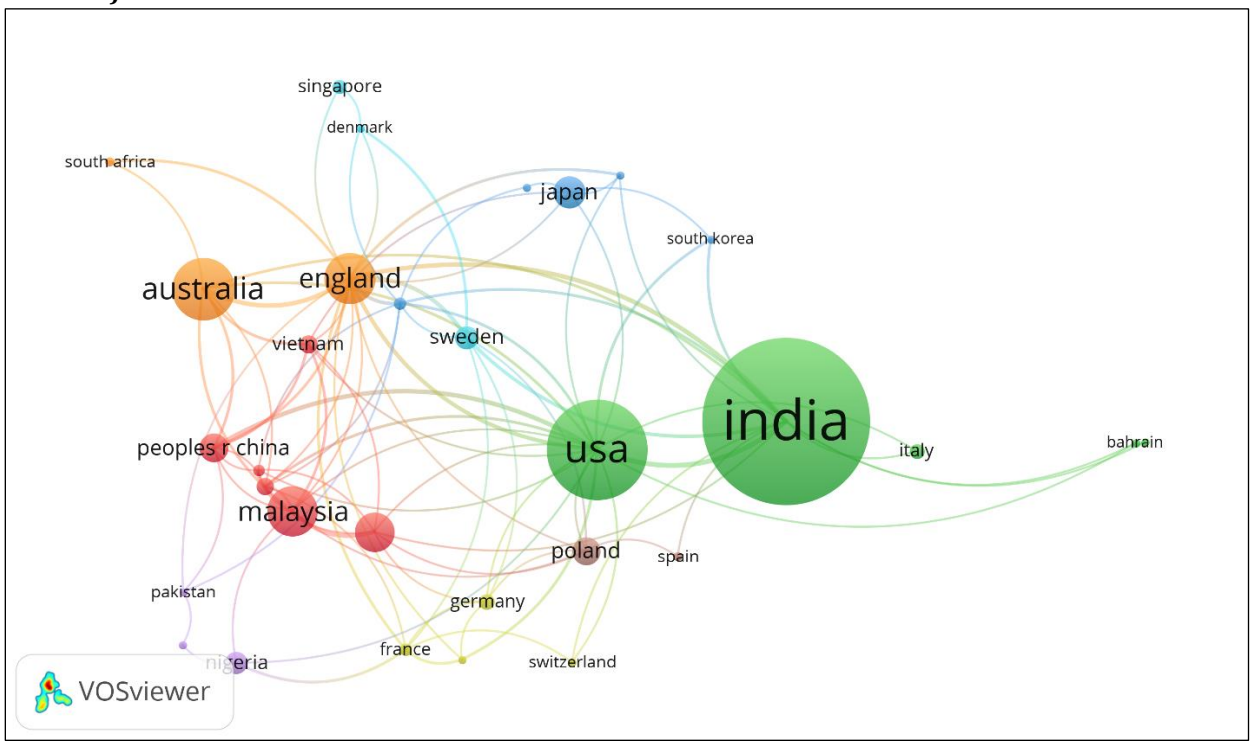


Figure 5 shows global collaboration in financial literacy, financial payments, cashless payments, COVID-19 and mobile banking. India is marked as one of the countries with the highest number of research collaborations, frequently partnering with nations such as the United States, England, Australia, and Malaysia. Other prominent partnerships include those between the United States of America (USA) and Malaysia, the Republic of China, Poland, and Sweden, as well as between England and Malaysia, the Republic of China, Australia, Vietnam and Japan. Collaborations among countries across different continents underscore the global dimension of scientific research and academic publishing efforts. These collaborations represent meaningful partnerships in advancing research on financial literacy and cashless payment systems. India has engaged in collaborations with other countries such as Italy, Bahrain, South Korea, Spain, and Switzerland, but the number of these partnerships remains relatively limited (with one collaboration individually). Other countries also collaborate, such as Pakistan, which had collaborations with three countries, namely England, the Republic of China, and Nigeria, followed by Denmark with Sweden and Singapore, and France with Germany, Switzerland, and Nigeria. These findings highlight the growing need for enhanced collaboration across countries and continents, as international research partnerships facilitate the exchange of knowledge and expertise. By integrating diverse perspectives, methodologies and datasets, collaborative research contributes to the production of more comprehensive, nuanced and in-depth studies. Such cooperation also allows researchers to better understand how social, cultural, and economic contexts influence the adoption of cashless payment systems and financial literacy practices. Furthermore, these collaborations can help identify global best practices, inform financial education policies and support the creation of international standards and guidelines aimed at fostering a cashless society.

Figure 5: Network Visualisation Map of the Countries (Countries Collaboration Map from VOSviewer software)



Keyword Analysis from 2000 to 2024

The science mapping procedure is a combination of two basic processes (Boyack & Klavans, 2014; Öztürk et al., 2024), namely "analysis" and "visualisation". According to Comerio & Strozzi (2019), this procedure allows the author to represent keywords as the themes of research articles. Using VOSviewer, a keyword analysis was performed to explore the most prevalent themes in financial literacy and cashless payments. A total of 77 keywords with 790 total occurrences were identified across the 713 papers. Table 2 shows the leading 10 keywords used in financial literacy and cashless payments research between 2000 and 2024. The keyword "cashless" appears most frequently, with 38 occurrences, indicating its widespread use as a standalone conceptual term in the literature. Other commonly used keywords include "COVID-19" (29 occurrences), "cashless economy" (28 occurrences), and "cashless payment(s)" (53 occurrences), reflecting key themes and focus areas within the research landscape. A significant finding from the analysis of cashless keywords is that there is no unanimity on the conceptualisation of cashless payments and that a lack of standardised meaning compels authors to use the terms interchangeably. This resulted in the other keywords used representing cashless payments, i.e., mobile payment (20 occurrences) and mobile banking (18 occurrences). Additionally, most of the research uses the keyword financial literacy (21 occurrences), which also reflects financial inclusion (23 occurrences). This analysis produced significant findings that financial literacy has other domains used by researchers, i.e., financial behaviour, financial knowledge, and financial attitudes. This is because there is no consensus to finalise a standard and single concept for financial literacy.

Table 2: Top 10 keywords of financial literacy and cashless payments based on the occurrence

Keywords	Occurrences	Percentage
cashless	38	15%
COVID-19	29	12%
cashless economy	28	11%
cashless payments	28	11%
cashless payment	25	10%
financial inclusion	23	9%
financial literacy	21	9%

mobile payment	20	8%
cash	19	8%
mobile banking	18	7%

Sources: Summarised from VOSviewer

From the keyword searches, Figure 6 shows that 'cashless' is more widely connected with different terms such as payment, economy, e-payment, and society. This integration can clearly be seen through the density visualisation map of the author keywords in Figure 7. Meanwhile, financial literacy is also linked to cashless payments (Shehadeh et al., 2024b) as shown in Figure 8. As individuals are taking charge of their digital financial transactions after the pandemic, financial literacy has become equally and increasingly important. Financial literacy emerged as a core element during COVID-19, making it viable, as digital payments, mobile payments, and digital transactions were widely used during that time to avoid physical contact. However, the probability of more frequent cashless payments as a result of the pandemic differs considerably between countries, indicating the role of country-specific factors (Kotkowski & Polasik, 2021). Promoting financial literacy and cashless payments, for example, may reduce cash demand for transactions but not for hoarding in the case of Japan (Fujiki, 2020). Financial inclusion, financial technology, and digitalisation remain other emerging themes in the domain.

Figure 6: Network Visualisation Map of the Author Keywords

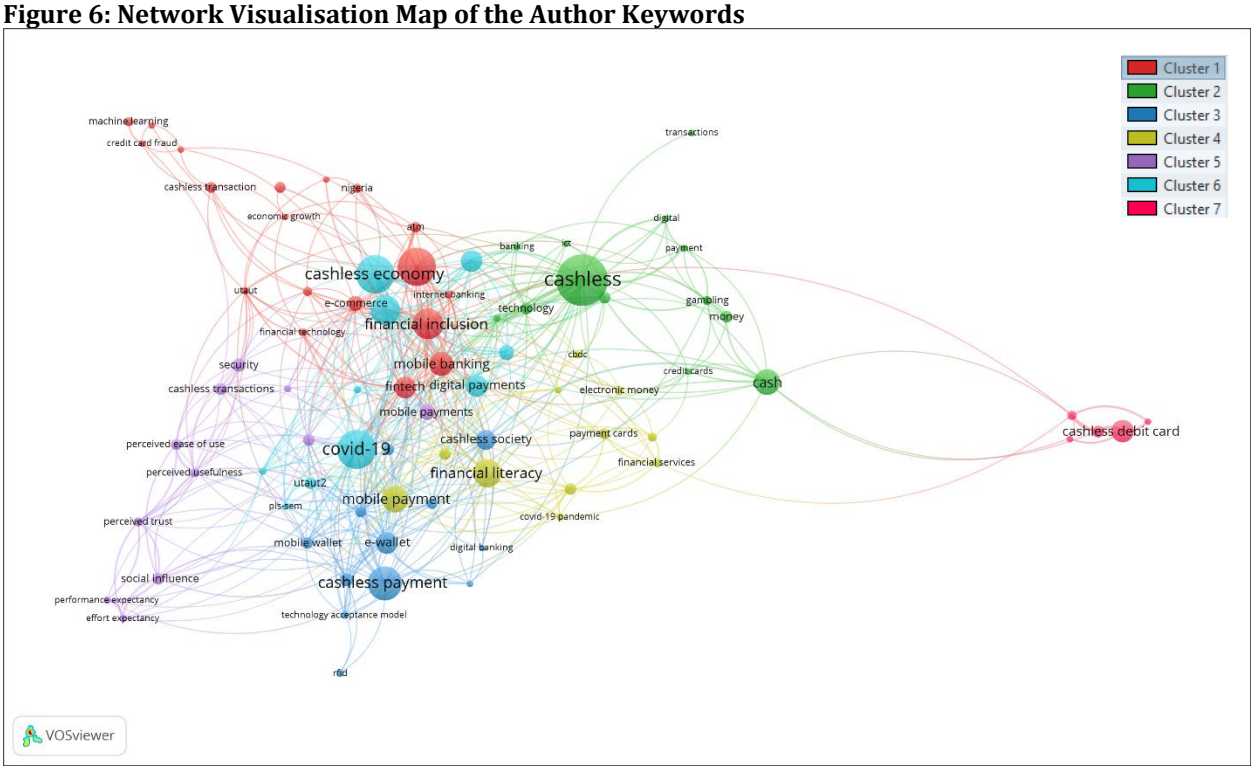
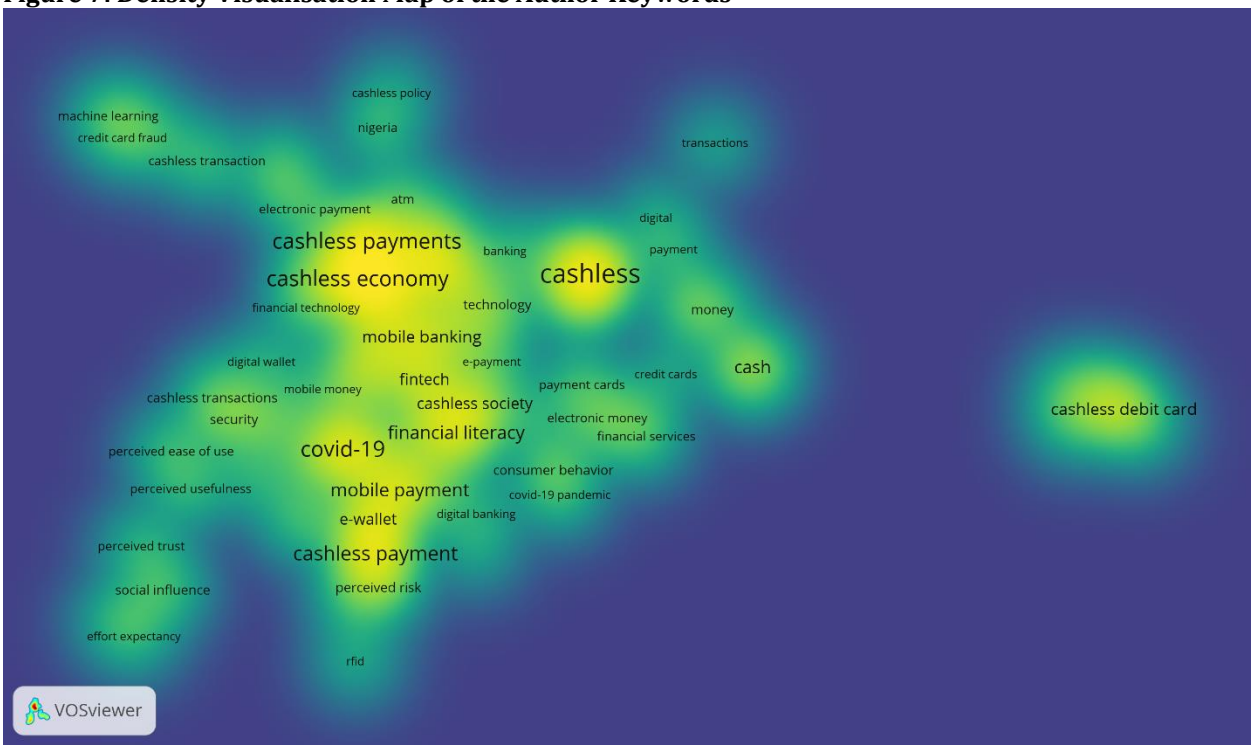


Figure 7: Density Visualisation Map of the Author Keywords



Cluster Analysis

From 2000 to 2024, 713 relevant articles published in journals extracted from the WoS database discussed diverse areas of financial literacy and cashless payment adoption. The bibliometric analysis will provide improved insight into the logical structure, further enhancing understanding of the domain and the work in its associated areas. This section thoroughly discusses the pertinent themes that emerged from the bibliometric analysis.

Cluster 1: Cashless Economy and Financial Inclusion

Studies within this cluster mostly focused on the way FinTech plays its role in economic growth, security, and financial inclusion. The cashless economy has gained significant attention in recent years, driven by advancements in FinTech and its role in fostering financial inclusion. Digital payment systems, including mobile banking and e-wallets, have transformed financial transactions, offering convenience and accessibility, particularly to unbanked and underbanked populations (Ozili, 2020). The shift towards a cashless society is closely linked to economic growth, as seamless transactions enhance efficiency and reduce costs associated with cash handling (Raya & Vargas, 2022). However, concerns regarding trust and security remain critical barriers to adoption, as users' perceptions of privacy, fraud risks, and regulatory protections greatly influence their willingness to embrace digital financial ecosystems (Apau & Lallie, 2022). Studies using bibliometric analysis indicate a growing body of literature on digital payment systems, with a focus on consumer trust, cybersecurity measures, and the role of government policies in promoting financial inclusion (Dissanayake et al., 2023). By analysing research trends, this study seeks to explore how digital payments drive financial inclusion while addressing security concerns that may hinder widespread adoption. Thus, the possible research angle within this cluster includes trust and security concerns in digital financial ecosystems, focusing on how digital payments drive financial inclusion.

Cluster 2: Adoption of Cashless Payments

In the cluster of adoption of cashless payments, studies often discussed mobile payments and e-wallets, where most of them applied the Unified Theory of Acceptance and Use of Technology (UTAUT) model to address digital and technology adoption among consumers. Researchers conducted studies focusing on the factors affecting digital payment adoption, specifically technology acceptance (Abdullah & Naved Khan, 2021; Raj et

al., 2024; Shehadeh et al., 2024b). This cluster area used various related keywords such as cashless payment, mobile payment, e-wallet, perceived trust, perceived usefulness, UTAUT, technology acceptance model to explain the adoption of digital payments, influenced by trust, security, and usability models like UTAUT and the Technology Acceptance Model (TAM). The main possible research gap to be explored is how perceived risk and trust affect e-payment adoption. Risk-averse people may be less likely to adopt and use e-payment services, while people with herd behaviour may tend to adopt and use e-payment services more (Königsheim et al., 2017; Bakar et al., 2020). In addition, the effects of financial literacy on the use and adoption of e-payment vary depending on individual behavioural traits (Long et al., 2023). This area of research can be applied in campus society as well as public society.

The predominance of UTAUT and TAM frameworks in this cluster reflects the field's grounding in information systems theory. However, a critical gap exists in integrating financial literacy as a moderating variable within these models. Existing adoption models largely treat users as technologically homogeneous, overlooking the role of financial knowledge as a precondition for meaningful technology engagement (Long et al., 2023). Future research should embed financial literacy constructs directly into UTAUT-based models to better explain variance in cashless payment adoption, particularly across different income and educational segments.

Cluster 3: Impact of COVID-19 on Financial Behavior
This cluster highlights the impact of the COVID-19 pandemic on financial behaviour, with a particular focus on the rapid acceleration of digital financial services and its implications for financial literacy. The pandemic catalyzed the widespread adoption of digital banking and e-payment systems, as consumers and institutions adapted to mobility restrictions and health concerns (Kotkowski, R., & Polasik, M., 2021; Raj et al., 2024). On university campuses, these changes were particularly pronounced, as students increasingly relied on contactless payment methods, online banking, and fintech platforms, reshaping their financial habits and interactions (Susanti & Reza, 2023). This shift underscored the importance of digital financial literacy, as individuals were required to navigate new technologies and financial tools in a rapidly changing economic environment (Koskelainen et al., 2023; Saxena, 2024). A potential research angle emerging from this cluster is the post-pandemic transformation in campus e-payment behaviour, especially how exposure to fintech during the crisis influenced students' long-term financial preferences and trust in digital financial systems. Overall, the cluster encapsulates a broader move towards a cashless society and highlights the role of crises in accelerating digital financial inclusion.

5. Conclusion and Implications

Directions and Suggestions for Future Research

This research on financial literacy and cashless payment adoption presents an analysis of bibliometric data sourced from the WoS database, aiming to unravel the implications, significance, and future directions stemming from this study.

Limitations

In terms of the limitations, the researchers only considered publications found in the WoS database. Other articles with the same keywords might be found in other databases such as Scopus, PubMed, and the Social Science Research Network. Additionally, articles published without a DOI and those accessible through open sources such as Google Scholar were excluded from the study. In addition, the search term "Financial Literacy and Cashless Payment Adoption" was used to find data for this study. Future searches in this area could yield a different or supplementary perspective by conducting studies on sociodemographic, economic, and risk preferences on cashless payment adoption.

Practical and Social Implications

This study offers a comprehensive overview of the current research landscape, providing direct guidelines for policymakers and financial service providers to design targeted interventions to improve financial literacy and encourage the adoption of secure, inclusive cashless payment systems. Insights from the bibliometric mapping can help fintech companies and mobile payment developers understand key research trends, user concerns, and financial literacy gaps, enabling them to develop user-centric products and effective awareness campaigns. In addition, educators and curriculum developers can use these findings to align financial literacy training with

emerging digital financial tools and behaviours, fostering better preparedness among students and low-literacy populations within the dynamic cashless economy.

Conclusion

This paper showed that bibliometric research is a significant scientific approach for both experienced and emerging scholars looking to delve deeper into a retrospective of broad and rich fields. This study provides a comprehensive bibliometric analysis of the nexus between financial literacy and cashless payment adoption, thus offering valuable insights into the intellectual structure and thematic evolution of the field. The findings reveal a growing scholarly interest in understanding how financial knowledge influences the adoption of digital payment technologies, highlighting critical themes such as trust, perceived risk, digital inclusion, and behavioural intention. As a subject that has drawn significant attention, particularly over the past few years, financial literacy and cashless payment adoption requires its preferable further research. The important themes identified in this study certainly provide significant, fundamental, and beneficial topics for future research.

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The Green Practices Outcome on Sustainability Performance: Evidence from Malaysian Manufacturing Companies

*Mashitah Mohamed Esa[1,2], Nor Fazilah Mohd Hashim[3], Mohd Shamsuri Khalid[3], Tooty Jamaludin[4]
[1]Faculty of Business and Management, Universiti Teknologi MARA, Puncak Alam Campus, Selangor, Malaysia
[2]Razak Faculty of Technology and Informatics, Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia
[3]Faculty of Artificial Intelligence, Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia
[4]Ideal Connectors, Malaysia
Email: *mashitah9803@uitm.edu.my
Corresponding Author: Mashitah Mohamed Esa

Abstract: Green practices have become an important strategic approach for manufacturing organisations seeking to improve sustainability while maintaining long-term competitiveness. Previous studies have extensively examined the environmental and financial benefits of green practices, and yet, limited research has explored their broader contribution to organisational performance from a qualitative perspective. This study explores the common green practices applied in the manufacturing industry and how these green practices contribute to organisational performance in Malaysian manufacturing companies. A qualitative multiple-case study design was adopted involving seven manufacturing companies located in Selangor, Malaysia. Data were collected through semi-structured interviews with ten informants, complemented by document analysis and workplace observations to strengthen the data credibility. Thematic analysis supported by NVivo software was employed to identify the recurring themes across the participating organisations. The findings reveal that green practices contribute to organisational performance through three interrelated dimensions: safety performance, economic performance, and organisational reputation. Green initiatives such as waste management and work process innovation improved resource efficiency, reduced operational waste, enhanced workplace safety, lowered operational costs, and strengthened stakeholder confidence. The study extends the existing literature by demonstrating that green practices create organisational value beyond environmental sustainability and should be viewed as strategic resources that enhance overall organisational performance. The findings provide practical guidance for manufacturing managers and policymakers in integrating environmental and operational strategies to achieve sustainable business performance.

Keywords: *Green practices; Sustainability; Safety benefit; Organizational performance; Manufacturing industry*

1. Introduction

Global manufacturing industries are experiencing increasing pressure to achieve sustainable growth while maintaining operational efficiency and organisational competitiveness. Increasing environmental regulations, stakeholder expectations, resource constraints, and market competition have encouraged manufacturing organisations to adopt green practices as part of their long-term business strategies. Rather than being viewed solely as environmental initiatives, green practices are increasingly recognised as organisational practices that can improve operational effectiveness, strengthen organisational resilience, and support long-term sustainability. In this context, green practices involve not only the adoption of environmentally responsible technologies and processes, but also the changes in employee practices, organisational procedures, management approaches, and work systems. Therefore, understanding the implementation and outcomes of green practices requires the consideration of both the technical and social dimensions of manufacturing organisations.

The manufacturing industry remains one of the largest contributors to economic development worldwide. In Malaysia, the manufacturing sector continues to play a significant role in national economic growth through employment creation, export earnings, technological development, and industrial development. However, manufacturing activities also consume substantial amounts of energy, raw materials, and natural resources while generating industrial waste, emissions, and occupational hazards. These challenges require organisations to adopt business practices that simultaneously support economic growth, environmental protection, operational efficiency, and employee well-being. Consequently, sustainable manufacturing requires organisations to consider not only the technical aspects of environmental improvement but also the people,

organisational structures, work processes, and management practices involved in implementing such improvements.

Green practices refer to organisational initiatives designed to minimise environmental impacts while improving the efficient utilisation of resources throughout business operations. Such practices include waste management, recycling and reuse programmes, energy efficiency, resource conservation, pollution prevention, and the adoption of environmentally responsible production technologies. These initiatives can enable organisations to reduce environmental burdens while improving operational processes and resource efficiency. Previous studies have reported that green practices can contribute to reduced energy consumption, lower production costs, improved environmental performance, enhanced operational efficiency, and strengthened corporate image. However, the benefits of green practices may depend on how these practices are implemented and integrated into existing organisational systems. The successful implementation of a green practice may require changes in the technology, production processes, employee responsibilities, skills, communication, management support, and organisational procedures.

The Socio-Technical Systems (STS) Theory provides a useful theoretical foundation for understanding these interactions. STS Theory views an organisation as a system consisting of interconnected social and technical subsystems. The technical subsystem includes technologies, machinery, production processes, workflows, and methods of resource utilisation, whereas the social subsystem includes employees, management, skills, communication, teamwork, organisational structures, and workplace practices. The theory emphasises that organisational outcomes are influenced by the interaction between these social and technical elements. From this perspective, the implementation of green practices should not be understood solely as the introduction of environmentally friendly technologies or procedures. Instead, green practices involve changes in the relationship between people, technologies, work processes, and organisational arrangements.

Despite the growing body of literature on green practices, previous research has primarily focused on environmental performance, financial performance, green innovation, or sustainable supply chain management. These studies have provided valuable evidence regarding the potential benefits of green practices; however, the findings are not always consistent across organisational and contextual settings. Some studies have reported that green practices improve operational efficiency, reduce costs, enhance competitiveness, and strengthen financial performance, whereas other studies have highlighted implementation costs, technological limitations, lack of expertise, organisational resistance, and resource constraints as challenges that may limit the benefits of green initiatives. These differences suggest that the relationship between green practices and organisational performance may depend on the organisational context and the manner in which green practices are implemented.

Furthermore, organisational performance should not be viewed solely through financial or environmental indicators. In manufacturing organisations, performance can also encompass operational efficiency, workplace safety, employee well-being, organisational reputation, and long-term sustainability. For example, waste reduction initiatives may improve resource utilisation and streamline production processes; energy management practices may reduce operating costs; cleaner technologies may improve workplace safety; and sustainable practices may strengthen stakeholder confidence and organisational reputation. These interconnected outcomes suggest that green practices can contribute to multiple dimensions of organisational performance. However, relatively limited attention has been given to understanding these interconnected outcomes from the perspective of organisations that have implemented green practices.

The dominance of survey-based quantitative studies represents a further limitation in the existing literature. Quantitative research is valuable for identifying patterns and examining relationships among variables across larger samples. However, it may not adequately capture the contextual experiences, implementation processes, organisational challenges, and meanings associated with green practices. A qualitative approach allows researchers to examine these issues in greater depth by tapping into how organisational members understand and experience green practices within their natural organisational settings. Interviews, observations, and document analysis can provide rich evidence regarding how green practices are implemented, how employees and managers respond to them, what challenges organisations encounter, and how organisational members perceive their contribution to performance.

This methodological gap is particularly relevant in the Malaysian manufacturing context. Although manufacturing organisations in Malaysia are increasingly encouraged to adopt environmentally responsible practices, comparatively limited qualitative evidence exists regarding how these organisations implement green practices within their day-to-day operations and how organisational members perceive their outcomes. Existing research has provided important insights into the adoption and performance implications of green practices, but less attention has been given to the experiences of organisations that have successfully implemented such initiatives. In particular, there is limited understanding of how technological changes interact with employee capabilities, management practices, organisational procedures, and production processes during the implementation of green practices in Malaysian manufacturing organisations.

This study addresses these gaps by exploring the green practices implemented by manufacturing organisations and how these practices contribute to organisational performance through a qualitative multiple-case study involving seven Malaysian manufacturing companies. Drawing on STS Theory, the study examines green practices as organisational practices involving the interaction between the technical and social elements. Through interviews, observations, and document analysis, the study explores how organisations implement green practices, how managers and employees experience these initiatives, how existing work processes and technologies are adapted, and how organisational members perceive the contribution of green practices to operational, safety, economic, and reputational outcomes.

The unique contribution of this qualitative study lies in moving beyond the predominantly quantitative question of whether green practices are associated with improved organisational performance to explore how green practices are implemented and how their contribution to organisational performance is experienced within the manufacturing organisations. The multiple-case design provides an opportunity to identify the common patterns and differences across seven Malaysian manufacturing companies and to examine how organisational contexts shape the implementation and outcomes of green practices. By focusing on organisational experiences, implementation processes, and interactions between social and technical elements, the study complements the existing quantitative evidence and provides a more contextual understanding of green manufacturing practices.

The study also contributes to the literature by adopting a broader perspective of organisational performance. Rather than examining environmental or financial performance in isolation, the study considers operational performance, safety performance, economic performance, and organisational reputation. From an STS perspective, these outcomes may emerge from the interaction between technical improvements and changes in social and organisational practices. Improvements in production technologies and processes may enhance operational efficiency, while employee training, participation, communication, and management support may contribute to safer and more effective work practices. Similarly, the successful integration of green practices may generate economic benefits through improved resource utilisation and cost efficiency and may strengthen organisational reputation through positive perceptions among stakeholders.

The findings of this study contribute to both theory and practice. Theoretically, the study extends the application of the STS Theory to the context of green manufacturing by demonstrating the importance of examining the interaction between technical and social elements when understanding the implementation and outcomes of green practices. Rather than treating green practices as isolated environmental initiatives, the study positions them within the broader organisational system in which technologies, employees, work processes, management practices, and organisational structures interact. The study, therefore, provides a socio-technical explanation of how green practices can contribute to multidimensional organisational performance.

Practically, the findings provide manufacturing managers with insights into the importance of integrating technical improvements with social and organisational considerations when implementing green initiatives. Investments in environmentally friendly technologies alone may not be sufficient to achieve sustainable organisational outcomes. Employee training, participation, management commitment, communication, appropriate organisational procedures, and effective integration of new technologies into existing work processes are also important considerations. Understanding these factors can help manufacturing

organisations implement green practices more effectively while achieving improvements in operational efficiency, workplace safety, economic performance, and organisational reputation.

The study also offers policymakers valuable insights into promoting sustainable manufacturing practices in Malaysia. Policies that encourage green manufacturing should consider not only technological adoption and environmental compliance, but also the organisational and human factors that influence implementation. Supporting employee training, organisational capabilities, technological development, and knowledge sharing may help manufacturing organisations integrate green practices more effectively into their operations. Such efforts can contribute to the broader objectives of sustainable industrial development and organisational competitiveness.

Overall, this study argues that green practices should not be viewed solely as environmental initiatives or regulatory requirements. Rather, they can be understood as socio-technical organisational practices that involve the interaction of technologies, people, work processes, and organisational systems. By examining the experiences of seven Malaysian manufacturing organisations through a qualitative multiple-case study, this research provides insight into how green practices are implemented and how organisational members perceive their contribution to operational performance, safety performance, economic performance, and organisational reputation. In doing so, the study extends the existing research beyond the predominantly quantitative examination of relationships between green practices and performance, and provides a deeper understanding of the organisational processes and contextual conditions through which green practices contribute to sustainable organisational outcomes.

The structure of this paper is organised as follows. The next section reviews the literature on green practices. This is followed by the research methodology, which describes the qualitative multiple-case study design, case selection, data collection, and data analysis procedures. The findings are then presented based on the themes emerging from the seven cases, followed by a discussion of the findings in relation to previous literature and the STS theoretical perspective. The paper concludes by outlining the theoretical contributions, practical and policy implications, limitations, and directions for future research.

2. Literature Review

Green practices adoption

Green practices in the manufacturing industry are manufacturing processes that focus on efficient production processes that use fewer materials, simplified processes, and safe manufacturing practices. Haile and Sing (2026) highlighted that the green practices embedded at the corporate level enhance the prospects of achieving long-term sustainability. Green practices encompass a range of environmentally sustainable initiatives, including green manufacturing (GM), green warehousing, green packaging, and green distribution (Wang et al., 2013). The implementation of these practices enables manufacturing firms to improve operational efficiency while minimising environmental impacts. Specifically, practices such as green manufacturing and green logistics contribute to enhanced product durability, efficient maintenance, reuse, refurbishment, and recycling, thereby supporting sustainable manufacturing operations (Umar et al., 2021).

Previous studies on green practices in the manufacturing industry have consistently identified green manufacturing and green supply chain management (GSCM) as the two most widely examined practices. Green manufacturing has been recognised as a key component of sustainable manufacturing and this has been extensively discussed in the literature (Wang et al., 2013; Ramayah et al., 2013; Sangwan & Choudhary, 2018; Afum et al., 2020; Umar et al., 2021; Wang et al., 2022). Similarly, green supply chain management has received considerable attention as a complementary practice that integrates environmental considerations throughout upstream and downstream supply chain activities (Ninlawan et al., 2010; Conding et al., 2012; Wang et al., 2013; Mardani et al., 2020; El-Mokadem & Khalaf, 2025). Supporting this perspective, Ramayah et al. (2013) incorporated both green manufacturing and green supply chain management as key dimensions for measuring manufacturing performance, highlighting their importance in improving organisational and operational outcomes.

Implementing a green-oriented business plan serves a dual strategic purpose: it secures a distinct competitive advantage while tangibly demonstrating an organisation's commitment to sustainable development (Sarkar et al., 2020). Beyond external positioning, integrating these green practices yields profound internal benefits, specifically enhancing the localised social sustainability within the workplace framework (Sroufe & Gopalakrishna-Remani, 2018, as cited in Govindan et al., 2021). The organisational impetus to adopt these eco-centric models is universally driven by a binary interplay of internal motivations and external pressures (Hasan et al., 2019; Yadegaridehkordi et al., 2023).

Internally, adoption is catalysed by deep-seated social obligations and aggressive competitiveness. Externally, coercive and market-driven pressures exerted by governments, regulatory mandates, non-governmental organisations (NGOs), customers, and local communities compel firms to reshape their operational paradigms (Khan et al., 2018; Hasan et al., 2019). Ultimately, this systemic shift across modern industries is a direct response to a broader public health and ecological crisis, aimed squarely at mitigating the systemic use of hazardous chemicals that drive air pollution, accelerate global warming, and compromise communities' well-being (Khan et al., 2018).

Green Practices Impact

From an environmental perspective, empirical evidence demonstrates that green practices through GM alongside complementary GSCM frameworks substantially mitigate the ecological footprint of industrial activities without triggering adverse environmental trade-offs (Afum et al., 2020). This is achieved through closed-loop manufacturing systems that contain waste, curb hazardous emissions, and optimise energy recovery through aggressive recycling and reuse protocols (Green et al., 2012; Bhool & Narwal, 2013; Sezen & Cankaya, 2013). Consequently, achieving benchmarks such as zero-pollution outputs and maximum material circularity directly correlates with measurable reductions in solid, liquid, and atmospheric waste streams (Yongge et al., 2009; Gao et al., 2019).

Economically, eco-efficiency directly translates into cost reduction and operational optimisation. Rather than acting as a financial drain, green practices catalyse productivity by minimising raw material consumption and lowering the expenditures related to environmental compliance and risk management (Atlas, 1998; Al-Hakimi et al., 2022). For small and medium enterprises (SMEs) in particular, the visibility of these tangible financial gains and operational efficiencies serves as the primary driver for adoption, ultimately mapping clear trajectories for sustained organisational growth (Ramayah et al., 2013; Sahar et al., 2020).

The social dimension of GM underpins long-term organisational sustainability and market competitiveness. Externally, low-impact production and responsible material selection bolster corporate reputation, cultivate stakeholder trust, and stimulate research and design (R&D) innovation (Ratnasingam & Wagner, 2009; Maruthi & Rashmi, 2015; Ghazilla et al., 2015). Internally, GM functions as a critical mechanism for occupational health and safety. By deliberately designing out process hazards, organisations can approximate targets of zero health damage and zero safety risks for operators—thereby safeguarding human capital, reducing accident-related liabilities, and mitigating occupational diseases (Yongge et al., 2009; Schulte et al., 2013; Mamtani, 2020).

3. Methodology

This study employed a qualitative multiple case study design to explore the implementation of green practices and their contribution to safety performance in the Malaysian manufacturing industry. A qualitative approach was appropriate as it enabled an in-depth understanding of organisational practices and the experiences and perspectives of practitioners involved in green and safety management. The multiple case design also facilitated comparisons across manufacturing organisations and the identification of common and case-specific patterns.

A total of 10 informants from seven manufacturing organisations in Selangor participated in the study. They comprised Safety and Health Officers, Safety Executives, Safety Engineers, Environmental Officers, Department Managers, and Senior Management Representatives. Participants were purposively selected based on their direct involvement in, or knowledge of, safety management, environmental management, green practices, or

operational activities. Access was obtained through the participating organisations and their designated representatives. Participation was voluntary, and informed consent was obtained before data collection.

Data were collected through semi-structured interviews, document analysis, and workplace observations. The interview protocol was developed based on the research questions and relevant literature and covered four main areas: safety performance, implementation of green practices, the contribution of green practices to safety performance, and implementation challenges. Open-ended questions and probing techniques were used to obtain detailed information and clarify participants' experiences. Interviews were conducted face-to-face according to the arrangements with each organisation and lasted approximately 2 hours. Interviews were audio-recorded with participants' permission and transcribed for analysis. Documentary evidence included environmental policies, sustainability reports, standard operating procedures, safety documentation, and certification records. Workplace observations provided additional contextual information on operational activities, green practices, and workplace conditions. These multiple sources enabled the triangulation of the findings.

The data were analysed using thematic analysis based on the six-phase approach of Braun and Clarke (2006). The process began with familiarisation through repeated reading of interview transcripts, observation notes, and documents. Initial codes were systematically generated using NVivo and focused on information relevant to the research questions. Both literature-informed concepts and themes emerging from the data were considered. Codes were subsequently compared and grouped into categories, followed by the identification and review of broader themes across the cases. Themes were refined, defined, and named before the final findings were developed. Data from different informants and organisations were continuously compared to identify the similarities and differences in the implementation of green practices and their contribution to safety performance. Data collection and analysis were conducted iteratively. Preliminary analysis informed subsequent interviews and helped determine whether new information was emerging. Data collection was considered sufficient when subsequent interviews generated limited new information, and the themes were adequately developed to address the research questions.

Permission to conduct the study was obtained from the participating organisations, and informed consent was secured from all participants. Participants were informed of the study purpose, the nature of their involvement, and their right to withdraw without penalty. Confidentiality and anonymity were maintained by removing personal identifiers and using pseudonyms or case codes for organisations. Research materials, including recordings, transcripts, and documents, were securely stored and accessed only by the researcher and authorised research personnel.

The trustworthiness of the findings was established based on credibility, dependability, confirmability, and transferability. Credibility was enhanced through methodological triangulation involving interviews, documents, and workplace observations, as well as the comparison of perspectives across participants and cases. Member checking was conducted to verify the accuracy of the transcription process by the researcher. Dependability was supported through the consistent use of a semi-structured interview protocol and systematic documentation of data collection, transcription, coding, categorisation, and theme development. NVivo facilitated the systematic organisation and retrieval of coded data. Confirmability was strengthened by grounding findings in participants' accounts and multiple sources of evidence, while an audit trail was maintained to document the development of codes and themes. Finally, transferability was supported through detailed descriptions of the research context, participating organisations, participants, and practices examined. Although the study does not seek statistical generalisation to all Malaysian manufacturing organisations, the detailed case descriptions allow readers and future researchers to assess the applicability of the findings to similar manufacturing contexts.

4. Findings

Based on the thematic analysis, Green Practices Activities and Green Practices Outcomes emerged as the two principal themes of this study. The findings indicate that manufacturing companies implement three primary categories of green practices, namely waste management, work process innovation, and management initiatives. These categories represent the key green practices adopted by the participating manufacturing

companies to support sustainable operations and enhance organisational performance. Moreover, the findings also highlight that the outcomes of green practices not only focus on environmental benefits but also indicate that the green practices contribute to safety improvement, cost benefits, and increased awareness among stakeholders.

Green Practices Activities

Waste Management- Waste management emerged as one of the main green practices implemented by the participating manufacturing companies. The findings indicate that companies classify waste into two categories, namely scheduled waste and general waste, to ensure systematic handling of waste while protecting the employees and the environment. The waste management system is crucial to provide sufficient resources and ensure effective waste management (Informant 3, Company A).

Scheduled waste refers to hazardous waste regulated under the Environmental Quality Act 1974 and the Environmental Quality (Scheduled Wastes) Regulations 2005. Companies are required to report the quantity and type of scheduled waste through the Electronic Scheduled Waste Information System (eSWIS) and ensure that waste is properly stored, handled, treated, and disposed of. Most companies appointed competent personnel certified by the Department of Environment (DOE) to manage scheduled waste and ensure compliance with regulatory requirements. The findings also revealed that companies strictly complied with the maximum storage limit of six months or 20 metric tons before disposal. (Informant 4, Company B; Informant 13, Company F; Informant 10, Company E). Compliance with these regulations was considered important in preventing environmental pollution and workplace hazards, particularly those associated with hazardous chemical spills. Scheduled waste such as electronic waste (e-waste) was also recovered through third-party contractors to extract reusable materials, particularly copper, demonstrating that waste recovery was integrated into manufacturing operations (Informant 7, Company D).

Other findings also highlighted that general waste consists of non-hazardous waste generated from production, warehouses, and office activities. Although reporting to regulatory authorities is not required, companies voluntarily implemented waste management initiatives to maintain workplace cleanliness and improve environmental performance. Common wastes included plastic, paper, cardboard, and packaging materials, which were segregated for recycling and reuse (Informant 4, Company B; Informant 7, Company D; Informant 13, Company F). Several companies also introduced employee engagement programmes to encourage waste collection and recycling, while others collaborated with suppliers by replacing disposable packaging with reusable containers that could be returned for subsequent deliveries (Informant 4, Company B; Informant 7, Company D). These initiatives demonstrate that waste management extends beyond regulatory compliance by promoting environmental awareness, resource efficiency, and continuous improvement within manufacturing operations.

Work Process Innovation

In addition to waste management, the findings identified work process innovation as another important green practice adopted by the manufacturing companies. Rather than relying solely on waste disposal, companies implemented innovative approaches such as recycling, reuse, and recovery to manage production waste more sustainably. These initiatives reduced waste generation, minimised disposal costs, improved resource utilisation, and generated additional operational and environmental benefits.

Recycling was identified as a key work process innovation implemented by the participating manufacturing companies. The findings revealed that companies recycle various waste materials, including plastics, paper, cartons, scrap metal, packaging materials, and production waste, to reduce waste generation and improve resource efficiency. Rather than disposing of reusable materials, companies process them into raw materials for future production or return them to suppliers for reprocessing (Informant 8, Company D; Informant 9, Company E). The recycling process begins with waste segregation at the source, where employees separate waste according to designated categories before collection by appointed personnel. Although the recycling of general waste is not subject to regulatory reporting, companies monitor the quantity of recyclable materials to evaluate their waste management performance. Several companies also collaborated with third-party contractors or suppliers to recover recyclable materials and maximise resource utilisation (Informant 8, Company D; Informant 9, Company E; Informant 13, Company F).

In addition to recycling, the findings identified reuse as another work process innovation adopted by manufacturing companies to minimise waste generation and improve resource utilisation. Reuse involves extending the lifespan of existing materials, equipment, or resources by applying them for the same or alternative purposes within company operations. This practice enables companies to reduce the consumption of new resources, minimise disposal costs, and support sustainable manufacturing practices (Informant 4, Company B; Informant 8, Company D). The findings revealed that companies implemented reuse initiatives in various operational activities. For example, Company D practised the return and reuse of packaging boxes from customers for subsequent deliveries, reducing the need for new packaging materials. Kaizen activity has also been acknowledged in encouraging employees to identify opportunities for repurposing unused tools, equipment, and materials through continuous improvement activities. These initiatives enabled unused resources, such as pipes, racks, and production components, to be modified and reused for different operational purposes, resulting in cost savings and improved process efficiency (Informant 8, Company D). Furthermore, reuse activities were found to support both environmental and social benefits. Company C demonstrated an innovative approach by reusing contaminated gloves classified as scheduled waste through an internal cleaning process. The activity not only reduced scheduled waste generation and disposal costs but also provided suitable light-duty work opportunities for employees with physical limitations or health-related restrictions (Informant 6, Company C).

Besides recycling and reuse, the findings identified recovery as another work process innovation adopted by manufacturing companies to manage waste sustainably. The recovery process involved transforming waste materials into usable resources or secondary products, thereby reducing disposal requirements and improving resource efficiency. The findings revealed that Companies B and C implemented recovery practices for different types of scheduled waste generated from their production activities, particularly oil sludge and paint sludge. Company B implemented an oil recovery process to address oil sludge generated from oil spillage during the filling process. Previously, the company relied on external contractors for waste disposal, which resulted in additional operational costs. To improve waste management efficiency, the company introduced an oil skimmer system that separates oil from water collected through the drainage system. This initiative reduced waste disposal costs by approximately 30% and prevented workplace hazards associated with oil spillage, particularly slippery floor conditions (Informant 4, Company B). Similarly, Company C applied recovery practices to manage paint sludge generated from its painting activities. Instead of disposing of paint sludge as scheduled waste, the company collaborated with an appointed contractor to recover the material and transform it into second-grade paint for other users. This practice reflects the company's commitment to environmental protection by reducing waste disposal and promoting resource recovery in line with its ISO 14001 environmental management practices (Informant 6, Company C).

Besides waste management and work process innovation, the findings identified management initiatives as another important dimension of green practices adopted by manufacturing companies. Unlike operational-level practices, management initiatives require strategic planning, investment decisions, and collaboration with internal and external stakeholders to achieve long-term sustainability objectives. The main initiatives identified include energy management, water management, and GSCM.

Energy management emerged as a significant green initiative due to the high energy consumption associated with manufacturing operations. The findings revealed that companies implemented several strategies to improve energy efficiency, including solar energy installation, smart air systems, and the replacement of energy-intensive machinery. Solar installation was the most common energy management initiative adopted by the companies (Informant 2, Company A; Informant 4, Company B; Informant 6, Company C; Informant 8, Company D; Informant 9, Company E; Informant 14, Company F). By generating renewable energy from solar panels, companies were able to reduce their dependency on the electricity supplied by external providers, have lower operational costs, and support carbon reduction efforts. In addition to solar energy, a smart air system was used to optimise the compressor performance by maintaining appropriate air pressure and reducing unnecessary electricity consumption (Informant 6, Company C). A company also explored the replacement of the conventional machinery with hybrid machines to improve energy efficiency (Informant 14, Company F).

Water management was another important green initiative identified in the study. Companies implemented water conservation strategies through wastewater treatment plants (WWTP), water reclamation plants (WRP),

and rainwater harvesting (RWH) systems. These initiatives aimed to reduce the dependency on external water sources, minimise wastewater discharge, and improve water resource efficiency. The findings revealed that some companies integrated multiple water management practices into their production processes, such as WWTP and WRP, where treated wastewater was further processed and reused in production activities, creating a closed-loop water management system (Informant 6, Company C). WWTP and RWH were used to support production activities that required significant water consumption (Informant 15, Company G).

The findings further identified GSCM as a management initiative that extends green practices beyond the organisational boundaries by involving suppliers and customers. GSCM practices include green supplier selection, sustainable material sourcing, environmentally friendly packaging, and supplier collaboration. Companies required suppliers to comply with environmental requirements, such as providing Substances of Concern (SOC) certification and disclosing sustainability-related information. These requirements ensured that materials used in production were environmentally compliant and that they supported customers' sustainability expectations (Informant 15, Company G). Companies also collaborated with suppliers to reduce packaging waste through reusable packaging systems, returnable boxes, and rack-based delivery systems (Informant 8, Company D). The findings showed that supplier involvement remains a key challenge, particularly among small and medium-sized suppliers with limited awareness and reporting capabilities. Therefore, companies conducted supplier awareness programmes, assessments, and audits to encourage suppliers to gradually adopt green practices. Green readiness was also incorporated as one of the criteria in supplier selection and contract renewal decisions (Informant 2, Company A; Informant 4, Company B; Informant 8, Company D)

Green Practices Outcomes

The implementation of green practices contributes to several positive outcomes for manufacturing companies, particularly in terms of safety improvement, social benefits, economic benefits, and stakeholder awareness. The findings indicate that green practices should be viewed as a long-term investment that creates shared benefits for organisations, employees, and the environment.

The findings revealed that green practices contribute positively to occupational safety performance through both direct and indirect mechanisms. Effective management of hazardous waste, particularly scheduled waste, was identified as an important practice in reducing worker exposure to harmful substances (Informant 7, Company D). In addition, recycling and reuse activities contributed to safer working environments by promoting workplace organisation and reducing potential hazards such as slips, trips, and falls (Informant 3, Company A). Waste segregation practices also improved employee awareness and responsibility towards maintaining clean and safe work areas. Furthermore, reducing waste volume through recycling minimised manual handling activities, thereby lowering the ergonomic risks associated with lifting and transporting heavy waste materials (Informant 4, Company B; Informant 8, Company D). Recovery processes, such as oil recovery systems, were also able to reduce workers' exposure to hazardous substances and prevent safety risks caused by oil spillages (Informant 4, Company B). The findings further showed that green practices support hazard reduction through the adoption of safer materials and processes. By reducing the use of hazardous substances, companies were able to minimise employee exposure and strengthen preventive safety measures. These findings suggest that green practices complement traditional safety management approaches by addressing hazards at their source (Informant 3, Company A; Informant 15, Company G).

Other than safety benefits, economic benefits emerged as another significant outcome of green practice implementation. Although some initiatives require considerable initial investment, companies reported long-term financial benefits through cost reduction, resource efficiency, and additional income generation. Energy and water management practices, particularly solar installation and water conservation initiatives, contributed to the reductions in utility costs. Companies also recognised these initiatives as strategies to manage future risks associated with increasing energy and water prices (Informant 1, Company A; Informant 6, Company C). The findings also revealed that work process innovations, such as reuse and Kaizen activities, generated economic advantages by reducing the need to purchase new materials and equipment (Informant 8, Company D). In addition, recycling and recovery activities created opportunities for revenue generation through the sale of recyclable materials and recovered products (Informant 4, Company B). Some companies also shared income

generated from recycling activities with employees as a form of recognition and motivation, strengthening employee participation in green initiatives (Informant 13, Company F)

Beyond operational and financial benefits, green practices were found to enhance environmental awareness among employees and other stakeholders. The implementation of green initiatives encouraged employees to adopt more responsible behaviours, particularly in waste segregation, resource conservation, and workplace organisation. The green practices contributed to changes in employees' mindsets. Employees who previously lacked awareness of waste classification gradually developed a greater understanding and responsibility through continuous training and involvement in green programmes. For example, recycling campaigns and employee competitions encouraged active participation and strengthened engagement with sustainability initiatives (Informant 4, Company B; Informant 6, Company C). This finding, it showed that awareness among employees was identified as a critical factor in sustaining green practices. This continuous improvement, supported by top management, encouraged employees to actively contribute ideas and participate in environmental activities. These initiatives not only improved environmental performance but also fostered a culture of sustainability within organisations.

5. Conclusion

In conclusion, this study revealed that the green practices implemented by the companies began with efforts to preserve the environment through proper waste management, involving the handling of both scheduled and general waste, followed by the integration of recycling, reuse, and recovery processes within their production activities. These green initiatives were further expanded through management involvement in energy and water management practices, as well as the implementation of green supply chain management, which requires active collaboration and commitment from suppliers to support the organisations' sustainability efforts. By exploring the companies' green practices, this study shows that these practices generate significant safety-related benefits, minimise workers' exposure to hazardous materials through effective waste management practices and reduce ergonomic risks by decreasing the reliance on heavy and manual labour through recycling, reuse, and recovery processes. Furthermore, the findings highlight that the economic benefits derived from green practices adoption extend beyond environmental improvements, as efficient energy and water management contribute to sustained cost efficiency. These practices not only reduce the costs associated with waste disposal, but also create additional revenue streams through the sale of recyclable waste materials and the production of secondary-grade products. Moreover, the adoption of green practices has enhanced stakeholders' awareness of environmental initiatives, with continuous improvement systematically being integrated into organisational processes. This progress is further supported by employees' proactive involvement in sustainability programmes, reflecting a collective and long-term commitment towards corporate environmental responsibility. Overall, this study provides insights into how green practices are implemented within manufacturing companies, demonstrating that environmental sustainability initiatives can indirectly enhance safety performance. The findings highlight that green practices serve as a proactive approach to minimising potential harm to employees while providing a strategic pathway for organisations to strengthen their safety performance by leveraging the existing sustainability initiatives.

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FinTech Financing Platforms and Bank Lending to SMEs in Malaysia: Complements or Substitutes

*Nur'Asyiqin Ramdhan[1], Rohanizan Md Lazan[2], Norsaliza Abu Bakar[1]
[1]Faculty of Business and Management, Universiti Teknologi MARA, Puncak Alam Campus, Malaysia
[2]Faculty of Business and Management, Universiti Teknologi MARA, Johor Campus, Malaysia
Email: *asyiqin@uitm.edu.my, rohan134@uitm.edu.my, norsaliza@uitm.edu.my
Corresponding Author: Dr Nur'Asyiqin Ramdhan

Abstract: This study examines the complementarities or substitutability between financial technology (FinTech) financing platforms and bank financing for small and medium-sized enterprises (SMEs) in Malaysia. The study uses a six-variable structural vector autoregression (SVAR) framework, which includes the Overnight Policy Rate (OPR), Industrial Production Index (IPI), Consumer Price Index (CPI), peer-to-peer (P2P) financing, equity crowdfunding (ECF) capital raised, and aggregate outstanding SME bank loans, with monthly observations from 2017 to 2026. The SVAR results are complemented by structural impulse response functions (IRFs) with 95% bootstrap confidence intervals, forecast error variance decomposition (FEVD), diagnostic tests, stability assessment, and alternative lag specifications. The results show that P2P and ECF shocks generate small dynamic responses in SME bank lending and their 95% bootstrap confidence intervals generally include zero. An OPR shock produces a positive point response in SME bank lending, which is statistically distinguishable from zero only over part of the response horizon, while the P2P response is statistically distinguishable from zero only at an early horizon. FEVD results indicate that P2P and ECF shocks account for a growing share of the forecast-error variance of SME bank loans. Overall, the aggregate evidence does not provide robust support for a definitive complementarity, substitution, or fallback credit-valve mechanism.

Keywords: *FinTech, SME Financing, Bank Lending, P2P, ECF*

1. Introduction

Micro, small and medium enterprises (MSMEs) constitute a vital component of Malaysia's socio-economic structure, contributing 39.5% of the country's gross domestic product (GDP) and 48.7% of total employment in 2024 (Department of Statistics Malaysia [DOSM], 2025). Although these firms play a key role in localizing industrial production and job creation, they continue to face financing frictions. In this context, the rapid growth of financing platforms in the FinTech industry in Malaysia is significant because such platforms may reduce information asymmetry and transaction costs for credit-constrained SMEs (Sanga & Aziakpono, 2023).

The rapid use of alternative FinTech channels for financing has driven Malaysia to enact capital market guidelines that govern these sources. In 2015, Malaysia was the first region in ASEAN to introduce a formal regulatory regime for Equity Crowdfunding (ECF), and in 2016, Malaysia also introduced a formal regulatory regime for Peer-to-Peer (P2P) financing platforms (Securities Commission Malaysia, 2017). The amount of money raised in these digital alternative channels has grown exponentially over the past ten years, from a nascent financing avenue to a significant part of the national capital market architecture. But as these platforms grow in popularity and numbers, they pose an important macroeconomic issue for the structure of the domestic credit market. There are conflicting perspectives regarding the complementary role of digital lending to complement traditional financial institutions' credit offerings and the disruptive role of digital lending to challenge traditional banking models, potentially by substituting for conventional risk assessment systems (Agu et al., 2024). Empirically, it is unclear whether these FinTech financing platforms are complements or substitutes to the traditional banking system.

Despite the growing literature on financial technology, existing evidence does not establish a uniform relationship between alternative financing and traditional bank lending. Studies emphasizing complementarity argue that FinTech can expand access to underserved borrowers and generate information that may facilitate subsequent bank financing, whereas the substitution perspective suggests that alternative lenders may directly displace bank credit when they compete for similar borrowers. This distinction is particularly important in Malaysia because P2P financing and ECF represent debt- and equity-based channels with different balance-sheet implications. Moreover, much of the existing Malaysian evidence relies on annual, cross-sectional, or survey-based data, limiting the ability to examine the timing and persistence of financing shocks. The present

study therefore uses monthly data to investigate the dynamic interaction between P2P, ECF and SME bank lending while accounting for monetary and real-economy shocks.

The present study is an attempt to bridge these gaps in the empirical as well as methodological aspects. This study is conducted using a framework of Structural Vector Autoregression (SVAR), which produces high-frequency monthly time-series data from 2017 to 2026. The study objectives are:

- To estimate the impact of the volume of P2P financing on the volume of bank credit to traditional SMEs.
- To measure the impact of the ECF capital on the existing bank loans to SMEs.
- To examine the central bank monetary policy and macroeconomic shocks' propagation in both financing systems.

The remainder of this paper is structured as a series of well-connected and independent parts to allow for a systematic analytical flow. Section 2 provides a reviewed on the theoretical underpinning and empirical work. In Section 3, the econometric approach is described, including the identification framework for the SVAR, exclusion matrices, descriptions of the data, and estimation procedures. The empirical results are presented in Section 4, and a discussion of the findings is undertaken in Section 5. Section 6 highlights the discussion of the findings and an indication of the implications for structure and limitations to guide future research directions.

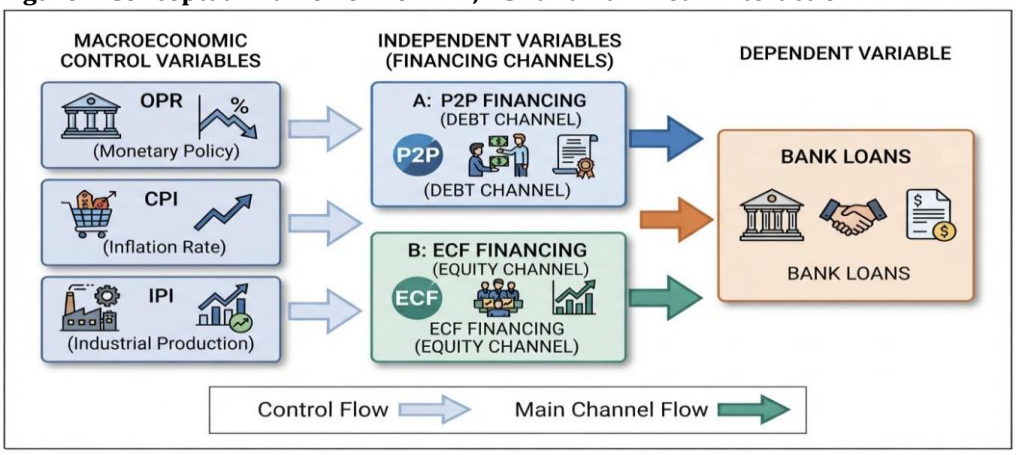
2. Literature Review

Theoretical Foundations

The integration of financial technology platforms and traditional financial institutions interacting on the structure of a credit market is derived from classical credit market theory as well as a classical theory on technological disruption. The theory of credit market failure is a basic paradigm that stems from Stiglitz and Weiss' (1981) Credit Rationing Theory. If the commercial banking institutions were to meet the increased demand for credit by increasing interest rates, they would have to deal with the problems of adverse selection and moral hazard in the presence of asymmetric information. The nature of bank requirements for collateral in project financing thus results in a non-price mechanism for risk management, which is one of the most significant constraints to financing projects for information-illiquid SMEs (Palmieri & Ferilli, 2024). In this context, FinTech platforms are used as a technological tool to overcome information asymmetry and use alternative, granular data to assess the creditworthiness of borrowers, which can help to reduce traditional bank rationing (Guo et al., 2025).

On the other hand, Christensen's (1997) Disruptive Innovation Theory predicts the substitution effect if digital lenders can offer lower costs to outcompete traditional lenders for borrowers with high-tech requirements and high-quality information (Ul-Durar et al., 2024). It establishes a complex relationship between traditional and relational banking practices, as well as transactional and data-driven banking practices (Nugraha et al., 2022). Digital IF can be used to tackle the "attribute-based mismatch" issue of traditional IF in emerging economies; however, empirical evidence from recent studies shows that FinTechs are increasingly emerging as a replacement for firms with limited capital access (Gaibulloev et al., 2025).On the one hand, the expansion of non-bank financing may broaden access to finance, and on the other hand, it may be associated with a rise in systemic risk in the overall system of institutional finance, which is called the "inclusion-stability nexus" by Banna et al. (2021). To evaluate the empirical relationship between digital alternative assets and institutional liabilities, the structural pathways between macroeconomic policies/decisions and volumes of alternative financing and the SME credit market need to be identified. This study does not consider FinTech as a single entity or a homogeneous entity but rather builds a dual-channel transmission model that comprises two channels: the debt channel and the equity channel. These alternative capitalization flows are not immune to today's innovations in both central bank monetary policy and the demand of the real economy (see Figure 1).

Figure 1:Conceptual framework of P2P, ECF and Bank loan interaction



P2P Financing Volume and SME Bank Loans

There is a highly controversial discussion on financial systems in the recent literature of banking and development economics on the part of financial technology platforms (P2P) versus the part of traditional commercial banking credit portfolios. This institutional setup depends on how much decentralized digital lending networks are used as a channel to expand markets or as a full-fledged and aggressive competitor. The results show that the digital providers are more likely to be direct substitutes in banking markets with greater concentration, and more likely to be complements in more dispersed banking markets in providing liquidity services. In addition, longitudinal evidence indicates that FinTech companies tend to take up the slack in the market for small loan applications, while also helping to meet the needs of more intricate and higher-value credit market applications that depend on traditional banking technology (Waliszewski et al., 2024; Cumming et al., 2021).

This strategic unit yields two empirically opposed ideas of complementarity and substitution. In the complementary paradigm, this solution suggests that the applications of peer-to-peer lending platforms are largely limited to a subprime, information-opaque, or even unrated SME segment that goes way beyond the risk appetite and regulatory mindset of commercial lenders. These platforms can supplement the lack of formal credit information, or they can use non-traditional data such as logistics performance and social media data to increase access to credit but without taking credit away from traditional banks (Iyer et al. 2015). Moreover, the rapid growth of P2P lending is now being considered in terms of indirect network externalities; the presence of institutions in digital platforms and the validation of borrower creditworthiness reduce the information asymmetries that have traditionally required banks' presence (Ribeiro-Navarrete et al., 2021). This relationship is made even better by the lower cost for banks in providing smaller credit facilities that are not very efficient to process (Farag & Johan, 2022). However, the substitution hypothesis implies that these platforms will become more competitive as they evolve and become more equally regulated in the future, and that this will lead to a shift in credit intermediation that is likely to be permanent, eroding the bank's traditional customer base (Kohardinata et al., 2023). Incumbent banks' market power and stability may be undermined by FinTech banks, as the competition may lead to smaller interest margins for incumbent banks (Cuadros-Solas et al., 2024; Naceur et al., 2025). As the share of portfolios decreases, incumbent banks are incentivized to be more competitive and/or riskier in their lending practices in this competition (Yin et al., 2022).

The market segment is structurally separated, which suggests that the conventional interest margins will be stabilizing in the long term, although the short term may experience competitive pressure and squeeze the interest margins. Traditional commercial banking networks are less efficient in underwriting the typical small, information-poor credit facility, and thus more prone to failure, so P2P systems that can underwrite credit facilities using data-driven models can strip away the liquidity requirement of commercial banks from the high-risk areas. This operational partitioning fills the credit void of firms that lack institutional forms and then comes back into the fold of the institutional matrix. But the outcome of a long-term coexistence is not an exclusive one, but a complementary one as alternative debt markets are forming in the Malaysian regulatory set-up. Hence, the following hypothesis is formulated:

Hypothesis 1 (H1): P2P financing is positively associated with SME bank lending over the longer response horizon, consistent with a potential complementarity or market-incubation mechanism.

Equity Crowdfunding (ECF) Volume and SME Bank Loans

An equity-based option of alternative financing refers to a variation of leverage in structure. This mechanism can be best understood through the structural parameters of the Pecking Order Theory: Companies would prefer internal financing and/or debt over equity financing because the latter dilutes the shareholder base and involves the strict disclosure requirements of the public capital markets. The Pecking Order Theory (POT) is a good example for explaining this mechanism, as it explains that corporations prefer to raise funds internally through debt and/or equity financing by preference, rather than equity financing, which results in ownership dilution and the rigorous capital market disclosure requirements (Eldridge et al., 2019). These platforms allow these companies to obtain capital to develop their innovation, which is hard to achieve when they are backed by debt-based financing, as the innovation is too risky for bankers (Laso et al., 2025). Stability under this alternative financing is available, but it is crucial that players also be integrated into institutional arrangements to diminish banks' fragility risk (Mamatzakis et al., 2021). Moreover, these platforms can be useful in solving the "principal-agent friction" associated with traditional intermediation, since the platform is able to match the capital needs and enhance the credit access of the SMEs, with a lesser amount of collateral (Block et al., 2017).

The use of ECF in overcoming these challenges can result in suboptimal capital structures; however, since the SMEs might be more focused on the immediate need for capital than the long-term strategic goals for the company, this may not be the best approach (Fasano et al., 2025). In the end, the rise of such platforms highlights the need to consider the whole landscape of entrepreneurial finance, in which intermediaries, both digital and traditional, must deal with intricate relationship dynamics to better address multiple market segments (Butticè & Vismara, 2021). Empirical evidence also indicates that the ownership of such platforms is likely to be associated with a higher debt load and/or lower internal liquidity of companies, suggesting a complementary rather than competitive relationship with traditional banking (Troise et al., 2024). A key difference with the traditional conventional banking filter for collateral for typical borrowers of ECF platforms differs from conventional banking, where it is early-stage startups, seed-phase companies, and asset-light innovative SMEs with high intangible asset capital (Hervé & Schwienbacher, 2018). These types of deals tend to fall short of commercial banks' strict interest coverage ratios, which makes them more likely to turn to ECF as a main gateway to evade the credit rationing that is common in traditional institutional settings (Mazzocchini & Lucarelli, 2022).

The digital platforms allow the transition and provide an important signal to investors, beyond financial needs, of the viability of the project, minimizing information asymmetries, which banks are not well positioned to solve (Estrin et al., 2022; Vismara, 2016). Conversely, studies have shown that the whole landscape is changing towards professionalization, as venture capitalists and business angels have entered these campaigns (Coakley et al., 2021). This new combination of expert signaling and retail investor capitalization may buffer early-stage investment risk and close the gap between informal financing and institutional VC investment (Wang et al., 2019). The developments demonstrated earlier illustrate that the sector is not just a displacement phenomenon, but an addition to the financial system, and an appealing source of capital which adds to the diversity of the entrepreneurial ecosystem (Estrin et al., 2018). This results in positive network effects that provide new pipelines and processes for the certification of deals in subsequent institutional funding rounds (Coakley & Lazos, 2021; Drover et al., 2017).

In contrast, while these ecosystem theories present equity crowdfunding as an additional signaling channel, it is also possible that corporate finance mechanisms are based on the Pecking Order parameters. In a situation of the credit market in Malaysia, if the campaign in the ECF is successful, the change in capital structure will be immediate, since commercial banking facilities require highly collateralized loans. Once the SMEs are able to acquire a long-term equity injection from crowd networks, they will have a huge cash buffer and become operationally independent of the commercial bank's overdraft and short-term loans at high rates of interest to maintain the flow of flexibility. In this sense, the current corporate optimization process is more about reducing debt and not the flow of banking connections. Therefore, the second hypothesis is:

Hypothesis 2 (H_2): ECF financing is negatively associated with SME bank lending over the longer response horizon, consistent with a potential substitution mechanism.

Macroeconomic Shock: OPR, Inflation and Industrial Output

Primary institutions of alternative digital finance and conventional finance are not isolated from the real economy or institutional changes by central bank monetary policy adjustments. In a risk-averse monetary policy, institutional credit constraints can also affect the monetary cost, with the risk of pushing small businesses towards the adoption of the crowdfunding approach (Camilleri & Bresciani, 2022). This is an example of a substitute relationship where companies have been moving to digital versions as bank credit has come in short supply in tight money markets. The three macroeconomic control variables are important to include in the monthly time-series modelling to isolate pure financial innovations. The three macroeconomic control variables are crucial in capturing the financial innovations and avoiding large omitted variable biases in the monthly time-series modelling.

The main policy channel through OPR is the conventional monetary transmission mechanism of the domestic credit market: the impact on the marginal cost of funds to SMEs from changes in commercial banks' prime rates because of the evolution of the liquidity situation. Any changes in the benchmark rate will thus directly affect the risk-adjusted return of the other credit sources and can also worsen the substitution effects observed during monetary tightening, as banks' credit is negatively related to credit from FinTech platforms (Khan et al., 2021). The tightening shock would manifest as the OPR hike by Bank Negara Malaysia resulting in commercial banks having to pay more for interbank funds. This therefore puts a conservative mindset on the credit sentiments of commercial lenders, who consequently have an impact on the credit sentiments of their SME customers, who rely heavily on external credit facilities for operating liquidity (Ololade, 2024). As a result, these credit-challenged firms are more likely to obtain liquidity from FinTechs that are not affiliated with a conventional bank but can readily provide them with credit when macroeconomic uncertainties arise (Finnegan & Kapoor, 2023).

The impact of these costs on the real economy is through the base lending rate and the reduction of loans outstanding, which means the risk of the asset is also reduced. Economic fluctuations usually occur in time series following a contraction of bank credit supply, since the contraction of credit supply can lead to a reduction in credit availability by lenders, who are worried about reducing default risk. (Wang et al., 2020). This institutional rationing causes a "credit vacuum" in the ability to access SME financing, but it's the technology-enabled platforms that will be able to make use of it, and not the traditional measures of creditworthiness that are often tied to collateral. Due to the tightening of traditional credit lines, other credit options are expected to increase even more, specifically in rate-sensitive or credit-rationed SMEs that are turning to online digital platforms, which should further accentuate the "effect of substitution" in the market (Degryse et al., 2018). The transition underscores the primary function of shadow banking and digital finance mechanisms to cushion the real economy during monetary contraction (Le et al., 2022). These relationships are consistent with previous theories on credit rationing that highlight the importance of interest rates in accessing credit and the information asymmetry of lenders and SMEs regarding liquidity constraints among SMEs (Gertler & Gilchrist, 1994; Le et al., 2021). The quality upgrading is similar with actioned when high-risk or marginalized borrowers are forced to switch to less regulated digital intermediaries during the systemic credit shock (Le et al., 2022). These alternative channels not only serve as a buffer to minimize negative shocks to the real economy from institutional credit rationing (Finnegan & Kapoor, 2023) but also provide a source of demand reduction for discouraged borrowers in lending (Brown et al., 2017).

In summary, the function of a systemic pressure valve in the credit market is the function played by the central bank interest rate policy. Monetary tightening causes commercial bank credit supply contraction due to risk aversion of commercial banks and tight interest rates, and is offset by digital alternative credit sources that absorb the contraction of commercial bank credit supply. This scenario leaves digital finance as a crucial macro shock absorber when monetary contraction is happening. Thus, the third hypothesis is formulated as follows:
Hypothesis 3 (H_3): A contractionary monetary-policy shock is associated with weaker SME bank lending and stronger P2P financing activity, consistent with a potential fallback credit-valve mechanism.

3. Methodology

Data Description and Model Specification

Monthly time-series data utilized in this study were sourced from Bank Negara Malaysia statistics and the Securities Commission's digital analytics websites. The total observations are 109 months from January 2017 to January 2026. The empirical variables are SME bank loans, P2P financing, ECF capital raised, OPR, CPI, and IPI. P2P and ECF are treated as monthly financing flows, whereas SMELOAN represents aggregate outstanding SME financing. Positive-valued financing and IPI series are transformed using natural logarithms; OPR and month-on-month CPI changes are retained in percentage form. No seasonal adjustment is applied because the source series are analyzed in their reported monthly form; possible seasonal patterns are therefore acknowledged in interpretation. Non-numeric spreadsheet cells outside the 109-observation sample are excluded from estimation.

Table 1: Variable Definitions and Data Construction

Variables	Definition	Transformation	Role
SMELOAN	Aggregate outstanding SME bank loans	ln(SMELOAN)	Dependent variable
P2P	Monthly P2P financing issuance	ln(P2P)	Alternative debt financing
ECF	Monthly ECF capital raised	ln(ECF)	Alternative equity financing
OPR	Monthly Overnight Policy Rate	Level (%)	Monetary-policy shock
CPI	Monthly month-on-month CPI change	Level (%)	Price shock
IPI	Industrial Production Index	ln(IPI)	Real-economy activity

$$\ln(SME\ Loan_t) = \beta_0 + \beta_1 \ln(P2P_t) + \beta_2 \ln(ECF_t) + \beta_3(OPR_t)z + \beta_4 (CPI_t) + \beta_5 \ln(IPI_t) + \varepsilon_t$$

The dependent market equilibrium variable is the natural logarithm of aggregate total outstanding SME loans issued by commercial and Islamic banking groups. $ln(SME\ Loan_t)$. The alternative financing channel of debt-based financing refers to the natural logarithm of monthly P2P financing issuance volumes. $\ln(P2P_t)$. The alternative financing channel of equity-based financing uses the natural logarithm of monthly ECF capital successfully raised. $ln(ECF_t)$. The primary monetary policy transmission instrument is the absolute monthly OPR percentage tier. (OPR_t). The structural baseline proxy for macroeconomic inflation (month-to-month changes) (CPI_t) and the purchasing power index is the natural logarithm of the Industrial Production Index.$\ln(IPI_t)$.

SVAR Identification Framework and Contemporary Restrictions

The conventional Vector Autoregression (VAR) models are limited by the arbitrary recursive ordering (Cholesky decompositions). The approach assumes that all the shocks to the variables in the system at the same time do not influence the subsequent variables in the system. To overcome this limitation, this study applies the Structural Vector Autoregression (SVAR) approach to decompose the economic shocks from the financial system of Malaysia. Mathematically, the reduced-form VAR model is given by:

$$Y_t = \sum_{i=1}^{p} A_i Y_{t-i} + e_t$$

The endogenous variables in this case are a matrix of endogenous variables, Y_t 6 X 1 in the Malaysian economy in a systematic order according to the structural responsiveness and the operational friction.

$$Y_t = [OPR_t, (\ln IPI_t), (CPI_t), (\ln P2P_t), (\ln ECF_t), (\ln SMELOAN_t)]$$

The sample contains 109 monthly observations for a six-variable SVAR and is therefore relatively small for a system of this dimensionality. The identification is kept parsimonious, and the results are interpreted cautiously. Dynamic estimates are evaluated using residual diagnostics, stability tests, bootstrap confidence intervals and alternative lag specifications rather than relying on a large-sample assumption.

Figure 2: The Matrix Composition Equation

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & 0 \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 \end{bmatrix} \begin{bmatrix} e_t^{OPR} \\ e_t^{IPI} \\ e_t^{CPI} \\ e_t^{P2P} \\ e_t^{ECF} \\ e_t^{SMELOAN} \end{bmatrix} = \begin{bmatrix} b_{11} & 0 & 0 & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 & 0 & 0 \\ 0 & 0 & b_{33} & 0 & 0 & 0 \\ 0 & 0 & 0 & b_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & b_{55} & 0 \\ 0 & 0 & 0 & 0 & 0 & b_{66} \end{bmatrix} \begin{bmatrix} u_t^{OPR} \\ u_t^{IPI} \\ u_t^{CPI} \\ u_t^{P2P} \\ u_t^{ECF} \\ u_t^{SMELOAN} \end{bmatrix}$$

The contemporaneous ordering is motivated by economic timing and institutional decision-making. OPR is placed first because monetary-policy decisions are made by the Monetary Policy Committee and respond to information available at policy-setting dates. IPI is placed before CPI because real activity can affect contemporaneous price conditions. P2P and ECF are placed after the macroeconomic variables because digital-financing activity can respond rapidly to current monetary and real-economy conditions. ECF is allowed to respond contemporaneously to P2P activity because both are alternative financing channels. SME bank lending is placed last because outstanding bank credit is a stock that adjusts more gradually to current shocks. These restrictions are economic timing assumptions rather than statistical identities; an alternative recursive ordering is therefore used as a robustness check.$e_t^{OPR} e_t^{IPI}$, $e_t^{CPI} e_t^{P2P}$, $e_t^{ECF}) e_t^{SMELOAN})$

4. Findings

Preliminary Analysis

To test the operational characteristics and historical changes in the compiled data, descriptive statistics are estimated for all variables after the transformation to natural logarithms (ln) to remove scaling differences and allow for constant elasticity parameters. However, the absolute percentage form is preserved for the OPR and the month-on-month changes in the CPI. The main summary metrics are given in Table 2.

Table 2: Summary Descriptive Statistics (T=109)

Statistic	*ln(SMELOAN)*	*ln(P2P)*	*ln(ECF)*	*OPR(%)*	*CPI(%)*	*ln(IPI)*
Mean	12.776	17.756	15.452	2.681	0.168	4.791
Maximum	12.990	19.548	17.169	3.250	1.300	4.951
Minimum	12.562	11.156	10.656	1.750	-1.400	4.379
Std. Dev	0.114	1.688	1.285	0.539	0.286	0.091

From the estimation, ln(SMELOAN) had a mean of 12.776 with a standard deviation of 0.114. Whereas ln(P2P) and ln(ECF) have means of 17.756 and 15.452, and standard deviations of 1.688 and 1.285, respectively. OPR averages 2.681%, CPI month-on-month change averages 0.168%, and ln(IPI) averages 4.791. These figures resembled a visual assessment of trends and an estimation of changes prior to the formal stability and integration tests.

The monthly trend of SME bank loans, P2P financing, and ECF capital raised from January 2017 to January 2026 is shown in Figure 3. The trend of SME bank loans is relatively stable and upward, while the trend of P2P financing is significant and shows a rising trend over the sample period, especially since 2020. ECF financing remains more volatile and at a substantially lower reported level than P2P financing. The figure provides descriptive evidence of the increasing scale of alternative financing, while the different measurement scales mean that the visual comparison of absolute levels should be interpreted cautiously.

Figure 3: Monthly SME Bank Loans and Alternative Financing

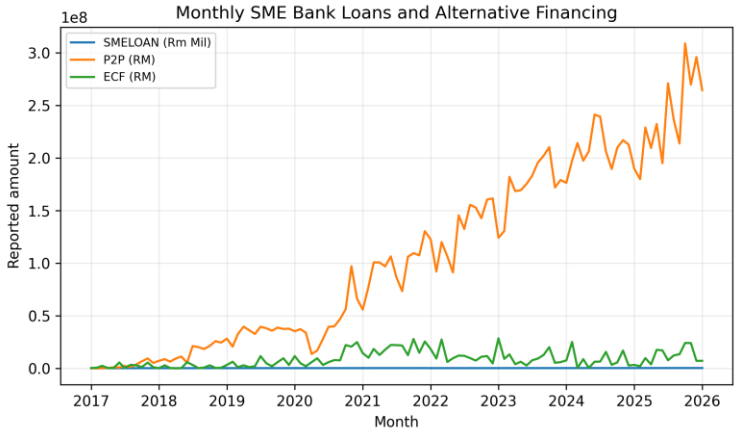
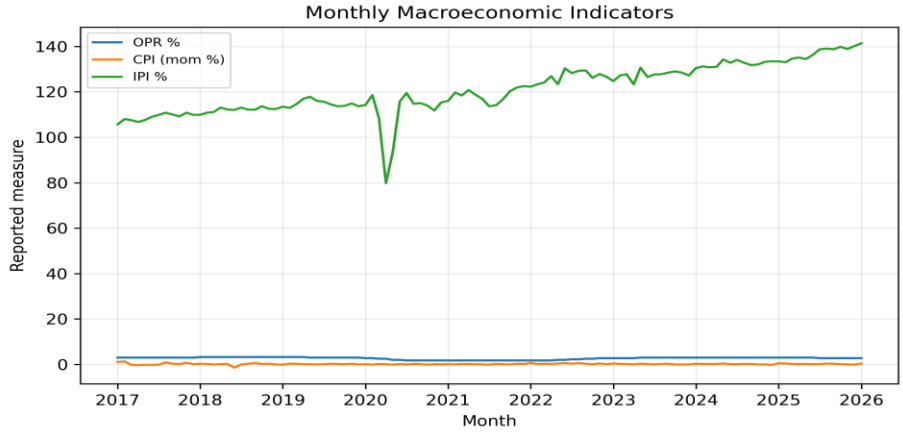


Figure 4 presents the monthly movements in OPR, CPI month-on-month changes and IPI. The series show a marked disruption around the COVID-19 period, including a sharp decline in IPI and a reduction in OPR, followed by a recovery in industrial activity and a subsequent normalization of monetary conditions. CPI month-on-month changes fluctuate around a relatively narrow range. These movements provide a visual indication of macroeconomic variation that may affect both conventional bank lending and alternative financing activity.

Figure 4: Monthly Macroeconomic Indicators



To avoid spurious regression results arising from non-stationary time-series data, the Augmented Dickey-Fuller (ADF) unit-root test is applied to each variable. The results in Table 3 indicate that ln(P2P), CPI and ln(SMELOAN) are stationary in levels, I(0), while OPR, ln(IPI) and ln(ECF) become stationary after first differencing, I(1). The mixed order of integration means that the variables cannot be treated as uniformly I(1). The Johansen analysis is therefore restricted to the I(1) subset, while the baseline SVAR is estimated using the transformed variables in levels as specified in the methodology.

Table 3: Augmented Dickey-Fuller (ADF) Unit-Root Test Statistics

Variables	Level	First Difference	Integration Status
ln(SMELOAN)	-0.643	-10.179***	I(1)
ln(P2P)	-5.025***	–	I(0)
ln(ECF)	-2.152	-5.765***	I(1)
OPR	-1.672	-3.962***	I(1)
CPI	-8.785***	–	I(0)
ln(IPI)	-0.625	-7.642***	I(1)

*Note: *** denotes rejection of the unit-root null at the 1% level. ADF lag length is selected automatically using the Akaike information criterion.*

Johansen Cointegration Analysis

The ADF results indicate that OPR, ln(IPI) and ln(ECF) are integrated at I(1); a Johansen cointegration test is conducted for this I(1) subset before drawing long-run conclusions. P2P, CPI, and ln(SMELOAN), which are I(0) in the revised spreadsheet, are not included in the Johansen system. The reported Johansen specification uses two lagged differences and a constant. Both the trace and maximum-eigenvalue statistics indicate one cointegrating relationship at the 5% level. This result supports a long-run relationship within the I(1) macro-financing subset, but it should not be interpreted as evidence of a long-run complementarity or substitution relationship between P2P/ECF and SME bank loans because the latter variables are I(0) in the reported ADF results. Note: The Johansen test is applied to the I(1) subset OPR, ln(IPI), and ln(ECF), using two lagged differences and a constant.

Table 4: Johansen Cointegration Test Results

Rank	Trace statistic	5% critical	Max-eigen statistic	5% critical
None	42.356	29.796	36.578	21.131
At most 1	5.778	15.494	3.704	14.264
At most 2	2.073	3.841	2.073	3.841

The AIC, SIC and HQ criteria reported in Table 5 select two lags in the reported estimation output. The two-lag specification is therefore retained as the baseline and is subsequently subjected to residual autocorrelation, heteroskedasticity, normality and stability diagnostics.

Table 5: VAR Lag Order Selection Statistics

Lag Length	LogL	AIC	SIC	HQ
0	-412.142	7.964	8.112	8.024
1	215.841	-3.845	-3.412	-3.671
2	284.125	-4.9128*	-4.214*	-4.625*
3	291.054	-4.814	-3.854	-4.425

** Indicates the optimal lag order selected by the respective criterion.*

SVAR Short-Run Contemporaneous Matrix Estimation Results

Following the optimization of the current structural restriction scheme using maximum likelihood, the current interactions between the variables are estimated in the same month. The estimated structural parameters of the target left-hand side contemporaneous matrix (A) are given in Table 6. The columns are independent variables that might bring about an abrupt change over the 30-day time frame, and the rows are dependent variables that would change directly because of the shock.($Ae_t = Bu_t$)

The contemporaneous structural matrix (A) is constructed to isolate the short-run transmission channels in the Malaysian SME credit market. The estimates indicate that the contemporaneous OPR coefficient in the SME bank-loan equation is negative and statistically significant (β = –0.384, p < 0.01), while the IPI coefficient is positive and statistically significant (β = 0.212, p < 0.05). In contrast, the contemporaneous coefficients for P2P financing (β = –0.056) and ECF (β = –0.021) are not statistically significant in the reported matrix. These contemporaneous coefficients describe immediate within-period relationships and should not be equated with the dynamic IRFs, which trace the response over subsequent months.

Table 6: Estimated Contemporary Structural Coefficients (Matrix A)

Affected Endogenous Variables (Rows)	ΔOPR_t	$\Delta\ln(IPI_t)$	CPI_t	$\Delta\ln(P2P_t)$	$\Delta\ln(ECF_t)$	$\Delta\ln(SMELOAN_t)$
ΔOPR_t	1.000					
$\Delta\ln(IPI_t)$	-0.154	1.000				
	(0.114)					
CPI_t	-0.092	0.114	1.000			
	(0.084)	*(0.075)*				
$\Delta\ln(P2P_t)$	0.284**	0.312***	0.185*	1.000		

	(0.124)	*(0.094)*	*(0.101)*			
$\Delta\ln(ECF_t)$	0.054	0.142*	0.094	0.215**	1.000	
	(0.048)	*(0.082)*	*(0.071)*	*(0.105)*		
$\Delta\ln(SMELOAN_t)$	-0.384***	+0.212**	-0.056	-0.056	-0.021	1.000
	(0.093)	*(0.087)*	*(0.055)*	*(0.055)*	*(0.032)*	

*Note: Standard errors are reported in parentheses ( ). Symbols ***, **, and * denote statistical significance at the 1%, 5%, and 10% rejection tiers, respectively.*

SVAR Diagnostic and Stability Tests

The two-lag VAR does not exhibit statistically significant multivariate residual autocorrelation at six lags (Portmanteau statistic = 153.753, p = 0.274). The multivariate normality test rejects normality (statistic = 17,165.951, p < 0.001). The univariate ARCH-LM results identify conditional heteroskedasticity in the ln(P2P) equation (LM = 22.186, p = 0.035), while the remaining equations do not reject homoskedasticity at the 5% level. The VAR satisfies the stability condition, with all inverse roots inside the unit circle. Given the non-normal residuals and the identified heteroskedasticity, bootstrap confidence intervals are used for the IRFs to provide more cautious inference.

Table 7: SVAR Diagnostic and Stability Tests

Diagnostic	Statistic	p-value	Assessment
Portmanteau residual autocorrelation, lag 6	153.753	0.274	No significant autocorrelation
Multivariate normality	17,165.951	<0.001	Normality rejected
ARCH-LM, ln(P2P), 12 lags	22.186	0.035	Heteroskedasticity detected
Stability	All inverse roots < 1	—	Stable VAR

Structural Impulse Response Function (IRF) Analysis

Figure 5 shows that a P2P financing shock generates a small negative response in SME bank loans during the first three months. The point estimate then becomes positive from around Month 4 and rises gradually to 0.00151 at Month 12. However, the 95% bootstrap confidence interval contains zero throughout the 12-month horizon. Thus, the pattern is consistent with a possible delayed positive association, but it does not provide statistically significant evidence of long-run complementarity or a market-incubation effect.

Figure 5: Response of ln(SMELOAN) to a P2P Financing Shock with 95% Bootstrap Confidence Interval.

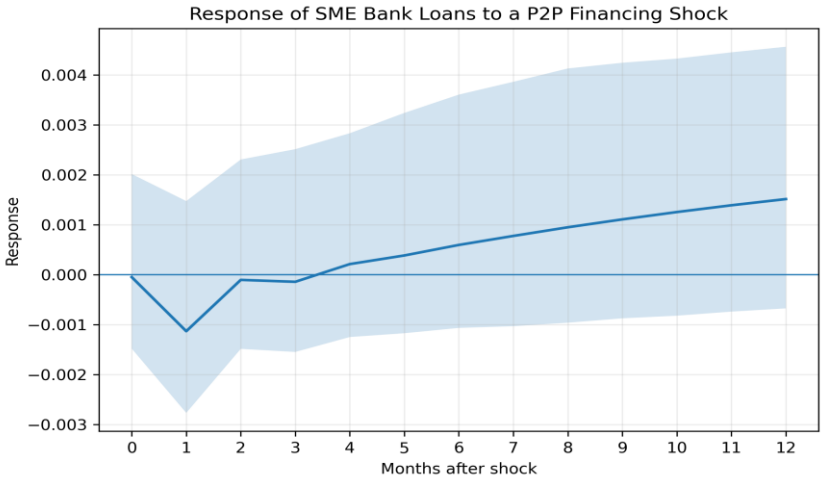


Figure 6 shows a negative point response of SME bank loans to an ECF shock throughout most of the horizon, with the response moving gradually toward zero and reaching approximately 0.00002 at Month 12. The 95% bootstrap confidence interval contains zero on the entire horizon. The evidence thus does not statistically confirm a substitution effect of ECF on SME bank lending.

Figure 6: Response of ln(SMELOAN) to an ECF Shock with 95% Bootstrap Confidence Interval.

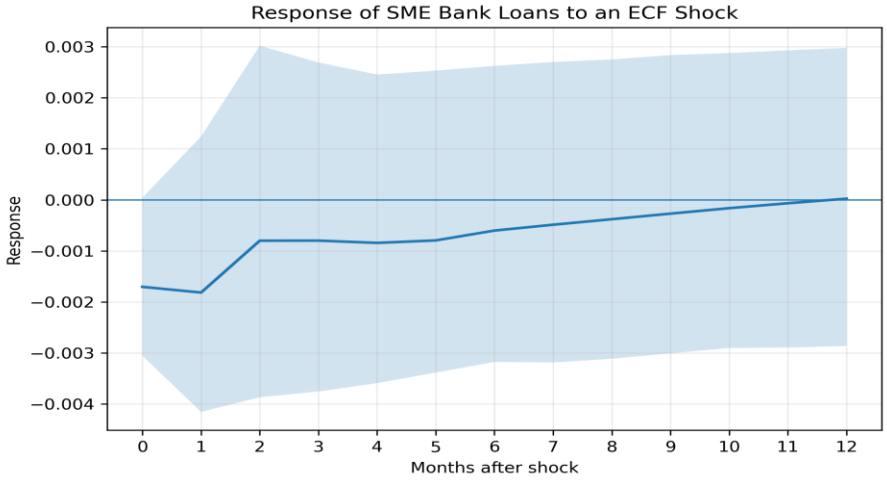


Figure 7 illustrates that the positive point response of SME bank loans to an OPR shock is positive, rising from around 0.0009 at Month 0 to 0.00512 at Month 12. The 95% confidence interval includes zero at the start of the horizon, is completely positive from about Months 5 to 10, and includes zero again at Months 11 and 12. The dynamic response is therefore positive in point-estimate terms, but the evidence is not uniformly significant across the 12-month horizon. This result does not support the hypothesized contractionary effect of an OPR shock on SME bank lending in the dynamic IRF.

Figure 7: Response of ln(SMELOAN) to an OPR Shock with 95% Bootstrap Confidence Interval.

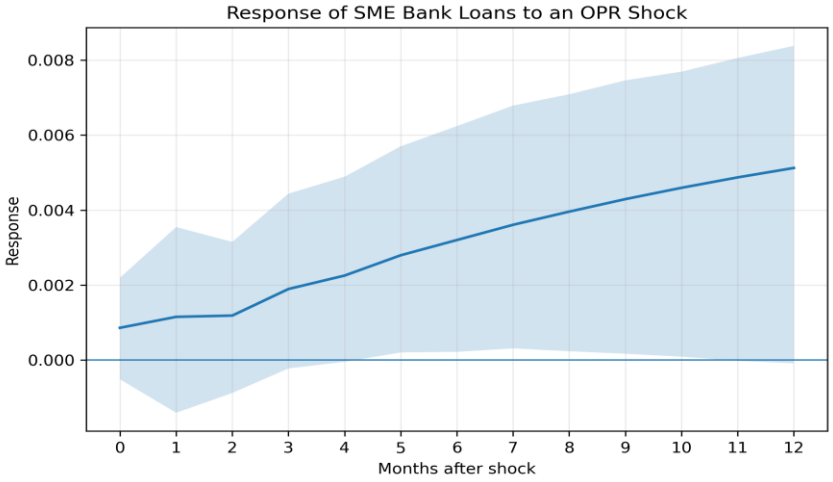
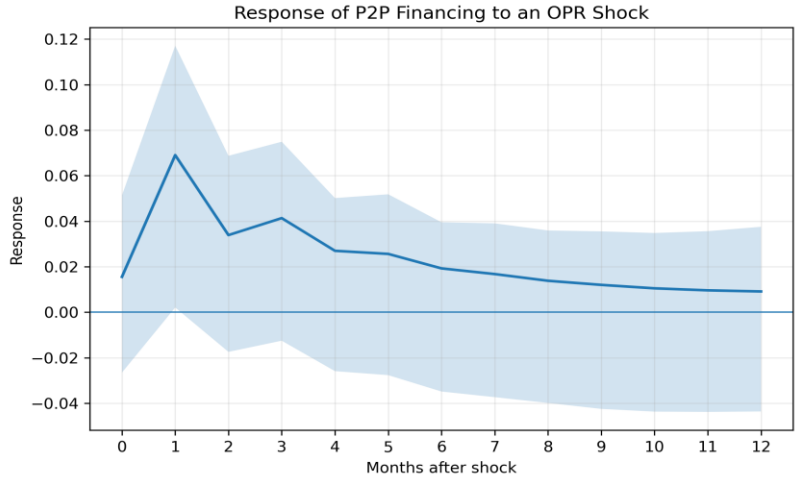


Figure 8 shows a positive point response of P2P financing following an OPR shock, rising sharply to 0.06903 at Month 1 and then gradually declining to 0.00912 by Month 12. The 95% confidence interval excludes zero only at Month 1 and includes zero thereafter. Thus, the response provides limited early-horizon evidence of increased P2P activity following an OPR shock, but it does not establish a persistent fallback credit-valve mechanism.

Figure 8: Response of ln(P2P) to an OPR Shock with 95% Bootstrap Confidence Interval



Forecast Error Variance Decomposition (FEVD) Results

The SME Bank Loans variable is then allocated using the FEVD approach, which allows for the isolation of the variation in the structure of SME bank loans available due to alternative digital finance, versus conventional macroeconomic drivers. The proportion of each structural shock to the total variance of the institutional credit portfolio for 12 months' forecast is presented in Table 8.

FEVD analysis indicates that the contribution of FinTech shocks to the forecast-error variance of SME bank loans increases over the forecast horizon. The own SME bank-loan shock remains the largest contributor at 53.14% in Month 12, while P2P and ECF shocks account for 17.12% and 6.56%, respectively. Thus, alternative financing shocks jointly explain 23.68% of the forecast-error variance of SME bank loans at Month 12. This indicates that FinTech shocks are economically relevant within the system, but FEVD does not by itself establish whether the relationship is complementary or substitutive. The interpretation is thus based on the FEVD shares, IRFs, and the coefficients at the time.

Table 8: Forecast Error Variance Decomposition of ln(SMELOANt) (%)

Horizon (Months)	Standard error	ln(*SMELOAN*$_t$) %	*OPR* %	ln(*IPI*$_t$) %	*CPI*$_t$ %	ln(*P2P*$_t$) %	ln(*ECF*$_t$) %
Month 1	0.011	91.24	3.12	2.45	1.14	2.05	0.00
Month 3	0.025	78.45	7.15	4.12	1.89	6.45	1.94
Month 6	0.039	64.12	11.24	5.84	2.14	12.45	4.21
Month 12	0.052	53.14	13.84	6.78	2.56	17.12	6.56

Note: The rows total 100% across each forecast milestone, and represent the systematic allocation of structural economic innovations over time.

Robustness Analysis

Robustness is evaluated with alternative lag lengths. Responses are orthogonalized and then recalculated for 12-months under one-, two-, and three-lag specifications. The aim is to determine if the direction and persistence of the primary responses are affected by the choice of lag. The same 109-observation sample and recursive ordering are maintained. The Month-12 P2P and ECF responses in Table 11 are reported as the alternative results and are found to differ in magnitude and sign depending on the lag length, suggesting some sensitivity to dynamic specification.

Alternative recursive identification is also explored by reversing the contemporaneous ordering of P2P and ECF, while keeping the macroeconomic ordering and SME bank lending as the last variable. The Month-12 P2P response is unchanged at 0.00151, and the ECF response is slightly adjusted from 0.00002 to −0.00002. The OPR response remains 0.00512. These results suggest that the main Month-12-point estimates are relatively stable for P2P and OPR, but the ECF response is sensitive to the contemporaneous ordering.

Table 10: Robustness Analysis Using Alternative Identification

Identification	P2P → SME loans, Month 12	ECF → SME loans, Month 12	OPR → SME loans, Month 12
Baseline: OPR–IPI–CPI–P2P–ECF–SMELOAN	0.00151	0.00002	0.00512
Alternative: OPR–IPI–CPI–ECF–P2P–SMELOAN	0.00151	-0.00002	0.00512

Table 11: Robustness Analysis Using Alternative Lag Lengths

Specification	P2P → SME loans, Month 12	ECF → SME loans, Month 12	OPR → SME loans, Month 12
VAR(1)	0.00310	-0.00031	0.00455
VAR(2)	0.00151	0.00002	0.00512
VAR(3)	0.00013	-0.00246	0.00450

Structural Break and Regime-Change Assessment

The sample spans the COVID-19 period and substantial changes in monetary and digital-financing conditions. A fixed-date Chow-type stability check, around March 2020, is thus reported as a sensitivity assessment. The test is based on comparing the pooled two-lag VAR equation with the pre- and post-March-2020 regressions separately. The evidence of a break is mixed across equations, and COVID-19 is therefore not considered a single deterministic regime shift, but rather a potential source of parameter instability. The OPR is specifically added to the system to reflect monetary-policy variation, and the time-series figures and stability-root test are used to gauge the overall financing environment. The regulatory change in the FinTech market is recognized as an additional institutional source of instability; as the dataset supplied does not contain a complete set of dated regulatory-event indicators, a full model of regulatory breaks is left for future research.

Table 9: COVID-19 Structural Break Assessment

Equation	Chow-type F	p-value	Assessment
OPR	2.104	0.022	Break detected at 5% level
ln(IPI)	2.873	0.002	Break detected at the 5% level
CPI	2.443	0.008	Break detected at the 5% level
ln(P2P)	1.710	0.074	No Break detected at the 5% level
ln(ECF)	2.909	0.002	Break detected at the 5% level
ln(SMELOAN)	0.368	0.976	No Break detected at the 5% level

Discussion

The P2P Debt Channel and Market Incubation

There is limited evidence of a market-incubation/complementarity mechanism in the P2P response. The estimated reaction of SME bank loans to a P2P shock is slightly negative at first and positive in point-estimate terms after a few months, when the reaction is 0.00151 in Month 12. But the 95% bootstrap confidence interval contains zero across the entire horizontal axis. Therefore, H1 is not supported statistically; the pattern is indicative of possibly a positive association at some later time, but there is not enough evidence of the pattern to suggest long-run complementarity. The lack of an ability to observe actual movement of individual firms from P2P financing to bank lending limits the market incubation interpretation from being an observation of the actual process of the firms and should be considered a plausible mechanism.

The ECF Equity Channel and Capital Structure Shifts

The initial reaction to the ECF is negative for SME bank lending, and weakens to near zero by Month 12. There is a 95% chance that the bootstrap confidence intervals contain zero on the horizon. Thus, the statistical support for H2 will be rejected. Although the FEVD result shows the economic relevance of ECF shocks within the banking system in terms of bank loans to SMEs at Month 12, it should not be read as evidence that firms substitute bank loans for equity finance.

The ECF pattern is thus best viewed as a negative, but more-or-less statistically certain, pattern of dynamic response, rather than as an actual structural change from bank debt. The individual firm data cannot be used to determine whether firms are using ECF to lower bank borrowing, to raise overall investment, or to eventually revert to bank financing. The aggregate ECF response should not then be considered as evidence of long-term substitution by regulators.

The Macro Policy Valve and the Inclusion Stability Nexus

The hypothesized fallback credit-valve mechanism does not seem to be strongly supported by monetary-policy results. The OPR shock has a positive point response in SME bank lending for the first part of the horizon, but only over the middle part (Months 5-10), while the rest of the area is covered by confidence intervals that do not exclude zero. The P2P response is also positive, but it is not statistically significant before Month 1 and is statistically imprecise thereafter. Therefore, there is no persisting contractionary-credit-valve effect supporting H3. The variance share of OPR in the FEVD (13.84% at Month 12) does not necessarily imply that there is a statistically proven transmission channel.

5. Conclusion

Complements or Substitutes

The current study revisits the complement versus substitute debate in the SME financing sector in Malaysia, employing monthly data and a six-variable SVAR setup. According to the updated analysis, P2P and ECF shocks increasingly represent a share of forecast-error variance of bank loans to SMEs in the 12-month time horizon, accounting for 23.68% of the total in Month 12. The bootstrap IRFs, however, reveal that neither the P2P nor ECF response is statistically different from zero on the 12-month horizon. P2P response is positive in the first few months, and the confidence interval around the response is still broad and includes zero. The ECF response remains negative in point-estimate terms before approaching zero, with the confidence interval also including zero. The evidence therefore does not justify describing either channel as a definitive long-run complement or permanent substitute. Instead, alternative financing appears to be an economically relevant component of the broader SME financing system whose interaction with bank lending warrants continued monitoring.

Integrated Policy Recommendations and Future Research Framework

The findings have several policy implications. First, since P2P and ECF shocks jointly account for 23.68% of the forecast-error variance of SME bank loans at Month 12, BNM and SC Malaysia may benefit from coordinated monitoring across bank and non-bank financing channels. Second, the statistical uncertainty surrounding the IRFs suggests that regulation should avoid assuming a uniform substitution or complementarity effect across all SMEs. Third, non-normality and some heteroskedasticity support conservative inference when using high-frequency FinTech indicators for macroprudential surveillance. Fourth, the positive point response to an OPR shock should not be interpreted as evidence that monetary tightening expands bank lending; rather, it highlights the sensitivity of aggregate dynamics to the chosen structural identification. Finally, firm-level data are needed to determine whether the aggregate patterns correspond to actual transitions between P2P, ECF, and bank financing.

Limitations

Several limitations should be acknowledged. The analysis is conducted at the aggregate monthly level and cannot identify firm-level movements between alternative financing and bank credit. Diagnostic tests also indicate non-normal residuals and evidence of conditional heteroskedasticity in the P2P equation. The sample spans COVID-19 and changes in monetary and FinTech-market conditions, which may introduce parameter instability even though the baseline VAR satisfies the formal stability condition. Future research should consider longer samples, firm-level data, explicit structural-break or regime-switching models, and alternative methods such as local projections or Bayesian VARs.

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Integrating the Theory of Planned Behavior and the Norm Activation Model to Explain Prosocial Rumor Refutation

Erne Suzila Kassim[1], *Hanitahaiza Hairuddin[1], Sri Fatiany Binti Abdul Kader Jailani[1], Safwan Kamal[2]
[1]Faculty of Business and Management, Universiti Teknologi MARA, Kampus Puncak Alam, Selangor, Malaysia
[2]Faculty of Islamic Economics and Business, IAIN Langsa, Indonesia
Email: *nita_arif@uitm.edu.my, ernekassim@uitm.edu.my
Corresponding Author: Hanitahaiza Hairuddin

Abstract: During emergency crises, the rapid spread of social media rumours can threaten public safety and social stability. Although users can play an important role in countering misinformation, user-led rumour refutation remains underexplored as a prosocial digital behaviour. This study develops an integrated psychosocial framework that combines the Theory of Planned Behaviour (TPB) and the Norm Activation Model (NAM) to explain the rational and moral drivers of the intention to refute rumours. Data from 565 active social media users were analysed using Partial Least Squares Structural Equation Modelling (PLS-SEM) in SmartPLS 4.0. The findings show that attitude, social norm, perceived behavioural control, and, most strongly, personal norm significantly influence intention to refute rumours. Awareness of consequences, ascribed responsibility and online respect also significantly influence attitudes towards rumour refutation. Theoretically, the study demonstrates the value of integrating behavioural and moral perspectives to explain proactive responses to misinformation. In practice, the findings suggest that platform managers and crisis communicators should strengthen users' sense of responsibility, behavioural confidence, and respectful communication when designing misinformation interventions. Future research should examine the model across different populations, crisis contexts and digital platforms, and use longitudinal or experimental designs to assess whether these psychosocial factors translate into sustained rumour-refutation behaviour.

Keywords: *Social media rumors, Theory of Planned Behavior (TPB), Norm Activation Model (NAM), digital citizenship; prosocial behavior*

1. Introduction

When a rumor goes viral during a crisis, the question is not only why people believe or share it, but also who decides to stop it. Social media has fundamentally altered the way information circulates, allowing ordinary users to produce, reproduce, and challenge information with unprecedented speed. This decentralized structure can strengthen public communication, but it also enables unverified claims to travel faster than institutional verification can respond (Ali et al., 2023; Miró-Llinares & Aguerri, 2023). During crises, when uncertainty and public anxiety are already elevated, such rumors can distort risk perceptions, undermine institutional trust, and complicate crisis management (Abbas et al., 2022; Tasnim et al., 2020). Yet the same networked environment that enables rumors to spread also gives users opportunities to intervene.

This aspect has received significantly less theoretical attention. Existing research on misinformation has primarily focused on why individuals believe, consume, or disseminate false information, while comparatively little is known about the motivations behind voluntary user-led challenges to misinformation. Rumor refutation differs fundamentally from ignoring or avoiding questionable content. It requires individuals to recognize potential harm, determine that intervention is warranted, and act despite possible social disagreement or reputational risk. User-led rumor refutation thus constitutes a form of prosocial digital behavior that enhances the quality and resilience of the broader information environment. Because institutional fact-checking often cannot match the speed of viral information diffusion, users may serve as a critical layer of community-based defense against misinformation (Mirbabaie et al., 2020).

The question is what factors motivate individuals to actively correct a rumor when remaining silent would be less demanding? One explanation involves deliberative judgment. The Theory of Planned Behavior (TPB) posits that behavioral intention arises from attitudes toward the behavior, perceived social expectations, and perceived behavioral control (Zhao et al., 2016). In the context of rumor refutation, users may intervene because they value correcting misinformation, perceive social expectations to do so, and feel capable of taking action. Alternatively, moral obligation may play a role. The Norm Activation Model (NAM) suggests that

prosocial action occurs when individuals recognize the consequences of harmful behavior, perceive personal responsibility, and develop a personal norm that motivates intervention (Tang et al., 2022). Therefore, a user may refute a rumor not only because it is perceived as useful or socially endorsed, but also due to a sense of moral duty when others may be harmed.

These perspectives suggest that rational decision-making or moral motivation alone cannot fully explain rumor refutation. Notably, prior research has demonstrated the value of integrating TPB and NAM to capture complementary behavioral mechanisms, especially in contexts where prosocial and deliberative motivations coexist (Savari & Bagher, 2023). However, this theoretical integration has received limited attention in social media rumor refutation, where intervention decisions involve both assessments of the utility and feasibility of corrective action and perceptions of responsibility toward others.

Accordingly, this study develops a theory-integrated TPB–NAM framework to explain users' intentions to refute rumors on social media during crises. Rather than merely combining variables from two established models, the framework links two complementary explanations of intervention. TPB addresses the rational determinants of behavior, including attitude, subjective norm, and perceived behavioral control. In contrast, NAM emphasizes moral motivation, focusing on awareness of consequences, ascribed responsibility, and personal norm. Within this framework, subjective norm denotes perceived social expectations, while personal norm signifies an individual's internal moral obligation. Integrating these theoretical perspectives supports a more thorough understanding of rumor refutation by considering both behavioral and moral dimensions. Therefore, this study examines the factors influencing users' intention to refute rumors on social media during crises by integrating the TPB and NAM perspectives. Specifically, it examines how behavioral and moral factors explain users' intention to refute rumors

2. Literature Review

This section reviews past research on social media rumors, including research areas, factors that influence positive behavior in refuting and combating them, and indicators for combating rumors

Studies on Combating Social Media Rumors

Research on social media rumours has expanded across multiple disciplines, with significant emphasis on computational methods for detecting and tracing false information. Zhang, Gong, and Sinnott (2021) developed a rumour-detection tool that uses data-mining algorithms and user network analysis. Zishan & Yijun (2023) introduced a multimodal heterogeneous graph model to enhance detection accuracy. Xia et al. (2019) investigated rumour propagation by integrating self-purification mechanisms. Collectively, these studies underscore the effectiveness of computational techniques in identifying and modelling rumour diffusion. Nevertheless, their focus on detection and propagation offers limited insight into the factors that influence individuals' decisions to challenge or refute rumours.

Scholars have also investigated the characteristics and thematic content of rumours circulating online. Al-Zaman et al. (2020) analysed social media content and identified politics, health, education, crime, religion, and entertainment as common rumour themes. He et al. (2019) similarly reported that political and societal rumours were predominant on WeChat. Although these studies provide valuable insights into the types of rumours that circulate, they contribute less to understanding the psychological and social factors shaping users' responses. Thus, identifying rumour characteristics alone does not explain variation in individuals' active or passive responses.

Recent research has increasingly addressed strategies for responding to rumours. For example, Yu and Mustafa (2023), drawing on Situational Crisis Communication Theory (SCCT), examined government response strategies during health crises to mitigate rumours' impact on public perceptions. Dougrez-Lewis et al. (2022) assessed query formulation methods to enhance the effectiveness of rumour refutation, and Li et al. (2023) applied fuzzy-set qualitative comparative analysis (fsQCA) to identify configurational pathways linked to effective rumour refutation. While these studies advance the literature from detection to response, they predominantly emphasise response strategies, communication methods, and condition configurations, rather than exploring individual-level psychosocial determinants of rumour-refutation behavior.

Norm Activation Characteristics and Attitude Towards Combating Social Media Rumours

Awareness of adverse consequences refers to individuals' recognition of the potential harm caused by the spread of rumours on social media platforms (Zhao et al., 2016). Research by Pundir et al. (2021) concluded that a high level of awareness of the negative impacts of misinformation, fake news, and unverified content, such as emotional manipulation and increased grudges, was positively related to an individual's positive attitude towards taking action against rumours. Similarly, Tang et al. (2022) found that individuals more aware of the adverse consequences of false information were more supportive of interventions to counter rumours and exhibited more positive attitudes towards refuting them. These findings suggest that awareness of adverse consequences plays a crucial role in shaping individuals' attitudes towards combating social media rumours; thus, the following hypothesis is offered:

H1: Awareness of adverse consequences positively influences social media users' attitudes toward rumour-combating during social crises.

Ascribed responsibility pertains to individuals' sense of obligation or duty to address rumours circulating on social media platforms (Zhao et al., 2016). Nekmat and Kong (2019) investigated the role of perceived responsibility in rumour management and found that individuals who felt a greater sense of responsibility toward their community were more likely to engage in rumour-debunking activities. Furthermore, Tang et al. (2019) concluded that prosocial behaviours, such as altruism and moral obligations, which are related to responsibility, are important characteristics that explain support for efforts to combat misinformation. These findings suggest that ascribed responsibility positively influences individuals' attitudes.

H2: Ascribed responsibility positively influences social media users' attitude toward rumour combating in times of social crisis.

Online respect refers to the extent to which individuals value and prioritise respectful communication and interactions in online environments (Zhao et al., 2016). Debunking rumours is considered an act of respecting others in the online community. Pal et al. (2019) examined rumour debunking and the use of denials. They concluded that salient beliefs in denials are important in explaining attitudes. Additionally, individuals who placed greater emphasis on maintaining respectful online discourse were more supportive of efforts to combat rumours and promote accurate information sharing. Zubiaga et al. (2016) also analysed the role of different user types in segmenting users' reactions to false information. They found that highly reputable users who respect others are more careful about sharing information and ensure the content is accurate and supported by evidence. Therefore, based on the discussion, the following hypothesis is offered:

H3: Online respect positively influences social media users' attitude toward rumour combating in times of social crisis.

Theory of Planned Behavior and Social Media Rumors

The Theory of Planned Behaviour (TPB), developed by Ajzen (1991), provides a comprehensive framework for understanding human behaviour by considering attitudes, subjective norms, and perceived behavioural control. Attitudes toward rumour-combating behaviour refer to individuals' evaluations of engaging in activities to counter misinformation on social media platforms (Zhao et al., 2016). Pundir et al. (2021) found that individuals with more positive attitudes toward rumour correction and information verification are more likely to actively engage in rumour-combating behaviours. Moreover, Shahzalal and Adnan (2022) concluded that one's attitude predicted responsible social media use. These studies suggest the importance of how individuals perceive the truthfulness and accuracy of online information. Thus, based on the discussion, the following hypothesis is offered:

H4: Attitudes toward the rumour-combating behaviour positively influence social media users' intention to combat rumours in times of social crisis.

Subjective norms reflect individuals' perceptions of the social pressure to engage in a particular behaviour (Ajzen, 1991). Several studies have examined how subjective norms influence individuals' intentions to combat social media rumours. For instance, Zhao et al. (2016) found that individuals who perceive a strong social expectation to participate in rumour-correction activities are more likely to express intentions to engage in such behaviours. Similarly, Pundir et al. (2021) found that perceived social support for rumour correction positively predicts individuals' intentions to combat rumours. These findings provide support for H5 by

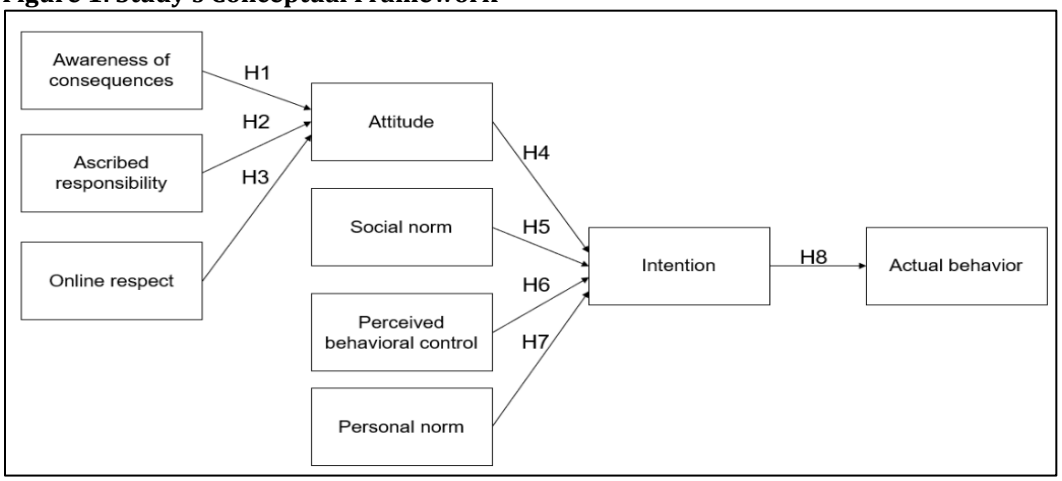
suggesting that subjective norms play a significant role in shaping individuals' intentions to combat rumours during social crises. Thus, the following hypothesis is offered:
H5: Subjective norm positively influences social media users' intention to combat rumours in times of social crisis.

Perceived behavioural control refers to individuals' beliefs about their ability to engage in a specific behaviour (Ajzen, 1991). Studies by Zhao et al. (2016) and Pundir et al. (2021) show that individuals who perceive greater control over their actions, such as having access to reliable information sources and effective rumour-refuting tools, are more likely to intend to combat rumours on social media platforms. Additionally, research by Shahzalal and Adnan (2022) found that perceived self-efficacy in identifying and correcting misinformation positively predicts individuals' intentions to engage in rumour-combating behaviours. These findings suggest perceived behavioural control positively influences individuals' intentions to combat rumours during social crises. Therefore, the following hypothesis is offered:
H6: Perceived behavioural control positively influences social media users' intention to combat rumours in times of social crisis.

Personal norm, rooted in the norm activation model (De Groot & Steg, 2009), reflects an individual's internalised sense of moral obligations. Studies in social psychology have shown that personal norms influence prosocial behaviours and altruistic actions; for example, research by Schwartz (1977). It is posited that individuals who prioritise refuting crisis-related rumours on social media during social crises will feel more obligated to take action to counter misinformation. Hence, the following hypothesis is offered:
H7: Personal norms positively influence social media users' intention to combat rumours during social crises.

Behavioural intention reflects individuals' readiness to perform a specific behaviour, while actual behaviour refers to the observed engagement in that behaviour (Ajzen, 1991). Zhao et al. (2016) concluded that individuals' intentions to combat rumours positively predict their actual engagement in rumour-correction behaviours on social media platforms. These findings provide support for H8 by indicating that individuals' intentions to combat rumours during social crises translate into actual behaviours. Thus, the following hypothesis is offered:
H8: Behavioural intention positively influences social media users' actual behaviour of combating rumours during social crises.

Figure 1: Study's Conceptual Framework



3. Methodology

Research Design

A quantitative, cross-sectional survey design was used to examine factors influencing social media users' intention to refute crisis-related rumours. This approach was selected to test theoretically derived relationships among multiple latent constructs within the integrated Theory of Planned Behaviour (TPB) and

Norm Activation Model (NAM). Partial Least Squares Structural Equation Modelling (PLS-SEM) was conducted using SmartPLS 4.0, as the study was prediction-oriented and involved a complex model with multiple latent constructs and hypothesised relationships (Hair et al., 2019, 2022). The analysis consisted of two stages: assessing the measurement model and evaluating the structural model.

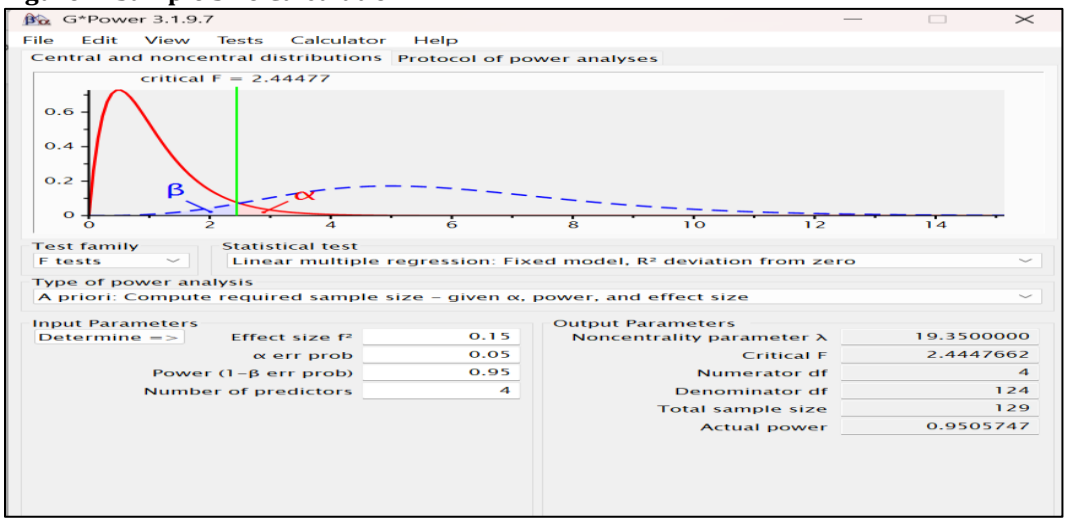
Instrument Development

The questionnaire comprised nine constructs: awareness of consequences, ascribed responsibility, online respect, personal norm, attitude, subjective norm, perceived behavioural control, intention, and actual behaviour. We adapted awareness of consequences, ascribed responsibility, online respect, and personal norm from De Groot and Steg (2009, 2010), while adapting attitude, subjective norm, perceived behavioural control, intention, and actual behaviour from Ajzen (1991). We contextualised the items to crisis-related rumour refutation while retaining the original measures' conceptual meaning. Specifically, intention to refute rumours was operationalised as the respondent's willingness or intention to actively challenge, correct, or clarify crisis-related rumours encountered on social media. We measured awareness of consequences with four items addressing the potential harm caused by crisis-related rumours. Ascribed responsibility included two items regarding users' responsibility to mitigate such harm. The two-item construct demonstrated acceptable reliability and validity in SmartPLS, supporting its adequacy for the present study. We assessed online respect with five items reflecting responsible and respectful online communication. Personal norm was measured with three items concerning moral and personal obligations to refute rumours. To help respondents understand the crisis context, the questionnaire provided examples of crisis-related situations, including flood-related misinformation and public-health concerns. All constructs were measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Before the main survey, experts reviewed the instrument to assess content relevance, clarity, and contextual appropriateness. The researchers then conducted a pilot test to evaluate item comprehension, wording, instructions, and response burden. The researchers revised items requiring clarification before the main data collection. The pilot results indicated satisfactory internal consistency, with reliability coefficients exceeding 0.70.

Participants and Data Collection

The target population consisted of social media users likely to encounter crisis-related information and rumours online. Purposive sampling was utilized to ensure that respondents possessed relevant social media experience appropriate to the study context. The minimum sample size was calculated using G*Power, based on the largest number of predictors for an endogenous construct. Figure 2 presents the sample size calculation. The analysis identified a minimum requirement of 129 respondents. Data collection spanned approximately three months, resulting in 565 responses, which substantially exceeded the required sample size. Data collection was conducted using an online questionnaire administered via Google Forms and distributed through email and WhatsApp. Participation was voluntary, and respondents were informed about the study's purpose and the confidentiality of their responses

Figure 2: Sample Size Calculation



Reliability, Validity and Common Method Bias

The measurement model was evaluated using indicator loadings, Cronbach's alpha, composite reliability (CR), average variance extracted (AVE), and the heterotrait–monotrait (HTMT) ratio. Reliability was deemed satisfactory when Cronbach's alpha and CR exceeded 0.70, and convergent validity was established when AVE exceeded 0.50 (Hair et al., 2019, 2022). Discriminant validity was assessed using HTMT, as recommended by Henseler et al. (2015), with values below 0.90 considered preferable and values below 0.95 acceptable for theoretically related constructs. Potential common method bias (CMB) was addressed procedurally by ensuring respondent anonymity, voluntary participation and clear item wording. Statistically, collinearity was assessed using the variance inflation factor (VIF), following Kock (2015). VIF values below the recommended threshold suggest that common method bias is unlikely to substantially affect the results. The measurement model demonstrated satisfactory reliability and convergent validity. As shown in Table 1, all indicator loadings exceeded 0.60. Cronbach's alpha values ranged from 0.709 to 0.881, and composite reliability values ranged from 0.819 to 0.926, all surpassing the recommended threshold of 0.70. AVE values ranged from 0.531 to 0.810, exceeding the minimum criterion of 0.50. These results indicate satisfactory internal consistency and convergent validity across all constructs (Hair et al., 2019, 2022).

Table 1: Reliability and Convergent Validity

Measure	Cronbach's Alpha (CA)	Composite Reliability (CR)	Average Variance Extracted (AVE)
Ascribed Responsibility	0.766	0.895	0.810
Attitude	0.856	0.903	0.701
Awareness	0.709	0.819	0.531
Actual Behavior	0.869	0.919	0.790
Intention	0.780	0.872	0.694
Online Respect	0.881	0.913	0.678
Perceived Behavioral Control	0.780	0.872	0.694
Personal Norm	0.751	0.858	0.668
Social Norm	0.879	0.926	0.806

Discriminant validity was assessed using HTMT, with results presented in Table 2. Most HTMT values were below 0.90. The highest value, 0.923, occurred between Online Respect and Intention, exceeding the conservative 0.90 criterion but remaining below the 0.95 threshold recommended by Henseler et al. (2015). In addition, the bootstrapped 95% confidence interval upper bound does not include 1.00, thereby establishing statistical discriminant validity (Henseler et al., 2015). Given the theoretical distinction between these constructs, this result does not indicate a critical discriminant validity issue. Overall, the HTMT results provide acceptable evidence that the constructs are empirically distinguishable. In general, the measurement model was assessed using the recommended criteria for reliability, convergent validity, and discriminant validity (HTMT), which are sufficient to establish measurement quality in PLS-SEM (Hair et al., 2019).

Table 2: HTMT Results

Measure	1	2	3	4	5	6	7	8
1. Ascribed Responsibility								
2. Attitude	0.620							
3. Awareness	0.639	0.451						
4. Actual Behavior	0.336	0.296	0.287					
5. Intention	0.582	0.558	0.521	0.529				
6. Online Respect	0.498	0.401	0.475	0.481	0.923			
7. Perceived Behavioral Control	0.424	0.449	0.442	0.478	0.687	0.587		
8. Personal Norm	0.650	0.531	0.574	0.551	0.88	0.866	0.791	
9. Social Norm	0.459	0.638	0.433	0.345	0.537	0.384	0.550	0.554

4. Findings and Discussion

Hypothesis testing utilized bootstrapping with 5,000 resamples to estimate standard errors, t-values, p-values, path coefficients (β), coefficients of determination (R^2), and effect sizes (f^2). One-tailed testing at a significance level of 0.05 was applied, as the hypothesized relationships were directional and supported by established theoretical propositions and prior empirical findings specifying the expected direction. The analysis assessed the effects of attitude, social norm, perceived behavioral control, and personal norm on the intention to refute social media rumors. Additionally, it evaluated the effects of awareness of consequences, ascribed responsibility, and online respect on attitudes toward rumor refutation. Confidence intervals were calculated to determine the precision and direction of the estimated relationships. Table 3 summarizes the results. The structural model assessment examined the in-sample explanatory power and statistical significance of the hypothesized relationships, aligning with the study's objectives of theory testing and driver identification.

Table 3: Hypothesis Testing

Hypothesis	Path Coefficient	Standard Error	t-value	p-value	LLCI	ULCI	Effect Size (f2)
H1: Awareness → Attitude	0.128	0.045	2.823	0.002	0.046	0.196	0.017
H2: Ascribed Responsibility → Attitude	0.388	0.065	5.983	0.000	0.282	0.493	0.153
H3: Online Respect → Attitude	0.147	0.045	3.276	0.001	0.072	0.219	0.024
H4: Attitude → Intention	0.159	0.046	3.430	0.000	0.088	0.240	0.034
H5: Social Norm → Intention	0.078	0.038	2.035	0.021	0.016	0.142	0.008
H6: Perceived Behavioral Control → Intention	0.160	0.044	3.631	0.000	0.089	0.233	0.031
H7: Personal Norm → Intention	0.479	0.054	8.785	0.000	0.385	0.564	0.275
H8: Intention → Behavior	0.448	0.040	11.216	0.000	0.380	0.511	0.251

R^2 attitude = 0.297 R^2 intention = 0.521 R^2 actual behavior = 0.201

The model accounted for 29.7% of the variance in attitude toward rumor refutation (R^2 = 0.297), 52.1% of the variance in intention (R^2 = 0.521), and 20.1% of the variance in actual behavior (R^2 = 0.201). These results indicate substantial explanatory power, particularly for intention, the central endogenous construct in the proposed TPB–NAM framework. All hypothesized relationships were statistically significant and thus supported. Personal norm was identified as the strongest predictor of intention to refute social media rumors (β = 0.479, $p < 0.01$), followed by perceived behavioral control (β = 0.160, $p < 0.001$), attitude (β = 0.159, $p < 0.001$), and social norm (β = 0.078, $p < 0.05$). Among the antecedents of attitude, ascribed responsibility exerted the greatest influence (β = 0.388, $p < 0.001$), followed by online respect (β = 0.147, $p < 0.05$) and awareness of consequences (β = 0.128, $p < 0.05$). These findings suggest that both deliberative considerations and moral obligation contribute to users' willingness to intervene against social media rumors, with personal norm constituting the primary motivational pathway. All hypothesized relationships were statistically significant, although their effect sizes varied considerably. Specifically, the effect sizes for awareness and attitude (f^2 = 0.017) and social norm and intention (f^2 = 0.008) were very small, indicating limited substantive contributions.

Discussion

The findings support a psychosocial model of social media rumor refutation that incorporates attitudes, social norms, perceived behavioral control, personal norms, ascribed responsibility, awareness of consequences, and online respect. These factors demonstrate significant associations with attitudes, intentions, and self-reported rumor-refutation behavior, although the magnitude of these relationships differs. Among the predictors of intention, personal norm exhibited the strongest association (β = 0.479, f^2 = 0.275), compared with attitude (β = 0.159, f^2 = 0.034), social norm (β = 0.078, f^2 = 0.008), and perceived behavioral control (β = 0.160, f^2 = 0.031). This stronger relationship suggests that an internalized sense of moral obligation is more closely linked to rumor-refutation intention than general evaluations, perceived social expectations, or perceived capability. Individuals who perceive refuting rumors as a personal responsibility are therefore more likely to report stronger intentions to act. This interpretation aligns with research highlighting the importance of responsibility and moral considerations in responses to misinformation (Zhao et al., 2016; Li et al., 2023).

Attitude and perceived behavioral control were also positively associated with intention, although their effect sizes were small. This finding indicates that favorable evaluations of rumor refutation and perceived capability are relevant, but their substantive contributions remain limited. These results are consistent with previous research linking positive attitudes, self-efficacy, and information-verification skills to responses to misinformation (Pal et al., 2019; Ding et al., 2022). Social norm demonstrated the smallest effect on intention ($\beta = 0.078$, $f^2 = 0.008$), despite reaching statistical significance. This result indicates a statistically significant but substantively limited association. A possible explanation is that users' own moral standards are more closely linked to rumor-refutation intentions than perceived expectations from others, particularly within diverse social media environments.

Regarding attitude, ascribed responsibility demonstrated the strongest association ($\beta = 0.388$, $f^2 = 0.153$), indicating that recognizing a personal responsibility to address misinformation is particularly relevant to developing favorable attitudes toward rumor refutation (Zhao et al., 2016; Li et al., 2023). Awareness of consequences ($\beta = 0.128$, $f^2 = 0.017$) and online respect ($\beta = 0.147$, $f^2 = 0.024$) also exhibited positive but relatively small effects. Awareness of misinformation-related harm may contribute to favorable attitudes, while respectful online interaction may facilitate a more constructive approach to challenging rumors (Zhao et al., 2016; Khraim, 2018).

Intention was positively associated with self-reported behavior ($\beta = 0.448$, $f^2 = 0.251$). However, because of the cross-sectional design and reliance on self-reported data, this relationship should not be interpreted as evidence that intention causes, or necessarily translates into, actual behavior. Instead, stronger reported intentions were associated with higher levels of reported rumor-refutation behavior within the study sample.

Implications and Contributions

This study extends the Theory of Planned Behavior (TPB) by incorporating moral and psychosocial factors, offering a more comprehensive understanding of intentions to refute social media rumors. Although TPB accounts for behavior through attitude, social norms, and perceived behavioral control, the findings underscore the importance of personal norms and ascribed responsibility in rumor-refutation responses. These results support integrating TPB with the Norm Activation Model (NAM), since rumor refutation may involve both deliberate decision-making and internalized moral considerations. This integrated approach enhances the conceptualization of rumor refutation as an aspect of responsible digital citizenship.

Practical implications should prioritize strengthening factors directly associated with rumor-refutation responses, rather than relying solely on broad awareness-based interventions. Educational and digital literacy programs may therefore emphasize developing users' sense of personal responsibility and moral obligation when encountering potentially harmful or inaccurate information. Such activities can encourage users to consider the consequences of sharing unverified information and to recognize their responsibility to respond appropriately.

Information-verification skills and behavioral confidence can support these efforts by enabling users to assess information critically and respond constructively. However, these initiatives should complement, not replace, efforts to cultivate personal responsibility and moral awareness. Likewise, social norms and online respect may be promoted through responsible communication and digital citizenship activities, acknowledging that their influence is likely supportive rather than central.

For social media platforms, practical measures may include prompts that encourage users to consider the consequences of sharing unverified information, accessible verification features, and mechanisms that promote respectful responses. These interventions can provide users with opportunities to exercise responsible decision-making when confronted with rumors. In summary, the findings indicate that practical efforts should extend beyond merely increasing awareness of misinformation and instead foster a combination of personal responsibility, moral awareness, verification skills, and constructive online communication.

5. Conclusion and Recommendations

This study investigated the factors influencing social media users' intention to refute rumors during crises by integrating the Theory of Planned Behavior (TPB) and the Norm Activation Model (NAM). The results indicate

that individuals do not refute rumors solely because they recognize false information. Their intention is also influenced by attitude, perceived social expectations, self-efficacy, and personal sense of responsibility. Among these variables, personal norm emerged as the strongest predictor of intention, while awareness of consequences, ascribed responsibility, and online respect shaped users' attitudes toward rumor refutation. The study underscores rumor refutation as a key aspect of responsible digital citizenship. In practical terms, interventions to reduce harmful rumors should focus on enhancing users' knowledge, confidence, sense of responsibility, and communication skills. Future research should investigate whether intention translates into actual, sustained rumor-refutation behavior across various platforms, user groups, and crisis contexts, using longitudinal or experimental methods.

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