ISCU 2025

17TH RISM INTERNATIONAL SURVEYING CONFERENCE FOR UNDERGRADUATES

Embracing Construction Revolution 4.0 (CR4.0): Transforming Malaysia's Built Environment

16th - 17th May 2025 I Friday - Saturday

E-ISBN PROCEEDING

VOLUME I

Published by
Royal Institution of Surveyors Malaysia
3rd Floor, Bangunan Juurukur
64 & 66, Jalan 52/4
46200 Petaling Jaya
Selangor

E- PROCEEDING 17th RISM ISCU 2025 Volume 1

Editors: Lizawati Abdullah, Nor Suzila Lop, Nor Nazihah Chuweni, Suriani Ngah Abdul Wahab, Hasnan Hashim

eISBN 978-629-94789-0-4

9 786299 478904

(online)

WELCOME SPEECH FROM THE CHAIRMAN

RISM 17th International Surveying Conference for Undergraduates (ISCU 2025)

بسم الله الرحمن الرحيم السلام

عليكم ورحمة الله وبركاته

Greetings to all,

It is with great pleasure that I welcome you to the 17th RISM International Surveying Conference for Undergraduates (ISCU 2025), themed *"Embracing Construction Revolution 4.0: Transforming Malaysia's Built Environment."* On behalf of the Royal Institution of Surveyors Malaysia (RISM), I also wish to express our sincere appreciation to Universiti Teknologi MARA (UiTM), Perak Campus, for graciously hosting this significant event.

As we navigate the era of the Fourth Industrial Revolution (IR4.0)—or in our context, Construction Revolution 4.0 (CR4.0)—we are witnessing transformative advancements across the global construction sector. Technologies such as Building Information Modelling (BIM), the Internet of Things (IoT), artificial intelligence (AI), robotics, big data analytics, and cloud computing are redefining the way we build, manage, and interact with our built environment. For Malaysia, embracing CR4.0 is a strategic imperative to achieve our socio-economic and environmental goals.

This conference serves as a vital platform to unite surveying undergraduates from various disciplines, fostering critical dialogue on industry challenges, enhancing professional networking, and preparing a new generation of talent for the rapidly evolving construction landscape. It is also an opportunity for employers to engage with and inspire our future professionals.

I would like to extend my heartfelt thanks to all industry speakers, paper presenters, judges, and participants for their time, contributions, and support in making ISCU 2025 a success. I also commend the organising committee for curating a meaningful and dynamic conference experience.

May the knowledge gained, connections formed, and ideas exchanged during this event inspire all participants to lead and innovate in their future endeavours.

Wishing everyone a productive and memorable conference.

Prof. Ts Sr Dr. Adi Irfan Bin Che Ani'
Chairman, Universities' Partnering Committee
RISM Session 2024/2025
May 2025

WELCOME SPEECH FROM CO-CHAIRMAN

RISM 17th International Surveying Conference for Undergraduates (ISCU 2025)

Bismillahirrahmanirrahim.

السلام عليكم ورحمة الله وبركاته and greetings to all.

It is my great pleasure to welcome everyone to the 17th International Surveyor Conference for Undergraduates (ISCU 2025), proudly hosted by Universiti Teknologi MARA (UiTM) Perak Branch in collaboration with the Royal Institution of Surveyors Malaysia (RISM). This event is a meaningful platform for students in the built environment to share ideas, showcase innovations, and build professional networks. We are honoured by your presence and enthusiastic participation, with 135 accepted papers and 78 poster presentations this year.

UiTM Perak, home to the College of Built Environment, has long been a hub for academic excellence in architecture, planning, and surveying. Our commitment remains strong in nurturing competent graduates who meet industry demands and contribute to nation-building.

While you're here, we invite you to experience the heritage and culture of Perak Tengah from the architectural richness of Rumah Kutai to the historical towns of Pasir Salak, Bota, and Kampung Gajah.

To all presenters and winners, congratulations on your achievements. Let your work today be a catalyst for future success and academic growth. We hope this conference will inspire you to explore new ideas, foster collaboration, and make lasting memories.

My deepest thanks to the Royal Institution of Surveyors Malaysia (RISM) and the organising committee for making this event a success.

We hope your experience here will be rewarding and unforgettable.

Thank you. Selamat datang dan selamat berjaya.

Associates Professor Dr. Nur Hisham Ibrahim, *PMP*
Co-Chairman, Universities' Partnering Committee
RISM Session 2024/2025
May 2025

WELCOME SPEECH FROM THE PROJECT DIRECTOR

RISM 17th International Surveying Conference for Undergraduates 2025

Alhamdulillah, all praise to Allah S.W.T. for His guidance and blessings in making the RISM 17th International Surveying Conference for Undergraduates (ISCU) 2025 a reality.

It is with great honour and gratitude that I welcome all participants, guests, academicians, and industry professionals to this prestigious event, proudly organized under the Royal Institution of Surveyors Malaysia (RISM). This 17th edition of ISCU stands as a proud testament to our collective dedication toward academic excellence, professional collaboration, and youth empowerment in the field of surveying.

I extend my heartfelt appreciation to RISM for its unwavering support, to the hardworking ISCU 2025 Organising Committee, and to all 16 partnering universities across Malaysia for their commitment and contributions. Your efforts have shaped this conference into a dynamic platform for knowledge exchange, innovation, and professional growth.

To the academicians and practitioners present, your insights are invaluable in bridging the gap between academic theory and real-world practice. To our undergraduate participants, your passion, curiosity, and commitment are the very foundation of our future. May this conference not only deepen your academic journey but also ignite a spirit of leadership, integrity, and sustainable thinking.

Let this gathering serve as more than an academic milestone. May it foster lifelong networks, inspire transformative ideas, and chart new directions in our shared professional journey.

Wishing everyone a rewarding and inspiring conference experience.

Sr Dr. Nurul Fadzila Zahari
Project Director
RISM 17th ISCU 2025

SUSTAINABILITY MEETS INNOVATION: UNLOCKING OPPORTUNITIES THROUGH EMERGING TECHNOLOGIES IN CONSTRUCTION

Lee Win Nie[1], Jeffrey Yap Boon Hui[2*]

Universiti Tunku Abdul Rahman, Cheras, Malaysia
Email: leewnie22@1utar.my
*Corresponding Author

ABSTRACT

Sustainability and innovation are increasingly shaping the future of the construction industry, with emerging technologies offering new opportunities to enhance environmental, economic, and social performance. This study aims to explore the role of emerging technologies in promoting sustainability in construction projects, identifying key advancements and their practical impact. Adopting a pragmatic paradigm with a quantitative research approach, the study employs a comprehensive literature review to deductively identify relevant technologies and sustainability potentials, forming the basis for a structured questionnaire. A field survey was conducted among experienced construction professionals with a total of 120 respondents including clients, contractors and consultants in Malaysia to gather perceptions of the relevancy and effectiveness of smart technologies in sustainability management. The collected data is analysed using descriptive and inferential statistics to derive meaningful insights. The key findings highlight the key drivers: regulatory and market influences, economic and competitive factors, technological advancements and innovation, environmental and resource considerations as well as competitive and strategic motivations. Also, the exploratory factor analysis uncovered four underlying factors influencing technology adoption: regulatory and environmental factors, technological and innovation factors, economic and market factors, social and sustainability factors, offering empirical evidence on industry readiness. The study bridges the knowledge gap between technological advancements and practical sustainability implementation by leveraging industry expertise while uncovering the underlying factors. Its novelty is providing a data-driven perspective on how smart technologies can be strategically integrated to optimise sustainability outcomes in construction project management. By aligning industry perceptions with emerging innovations, this study offers valuable insights for practitioners and policymakers, supporting the transition towards a more resilient and eco-friendlier built environment.

Key words: Sustainable construction, emerging technologies, resource efficiency, sustainability management, innovation

I. INTRODUCTION

Global environmental degradation, driven by human activities, has become a critical concern worldwide, manifesting through global warming, deforestation, biodiversity loss, and pollution. Countries with varying industrial practices and economic developments, such as China and African nations, face unique environmental challenges. For instance, China's industrial growth has tripled its carbon emissions between 1997 and 2018 (Hou *et al.*, 2021) while Foreign Direct Investment (FDI) in African countries often correlates with increased CO_2 emissions (Boubacar, Sarpong and Nyantakyi, 2024). Similarly, Central and Eastern European nations struggle with pollution and waste management due to rapid economic transitions (Christoforidis and Katrakilidis, 2022).

Malaysia, known for its biodiversity, is not exempt from these issues. Rapid urbanization and deforestation, primarily for palm oil plantations, have led to a 14.4% loss of forest cover from 2000 to 2012 (Zakaria and Singh, 2023), intensifying climate change impacts such as floods and droughts. These climate-related disasters have cost Malaysia approximately RM8 billion over the past two decades, while industrial activities contribute significantly to water pollution (Camara, Jamil and Abdullah, 2019).

To combat these environmental challenges, the construction industry is increasingly adopting smart technologies that enhance sustainability, efficiency, and safety (Hire, Sandbhor and Ruikar, 2022). Technologies such as Building Information Modeling (BIM), Internet of Things (IoT), and drones optimize project management, reduce waste, and improve safety. For instance, BIM can cut project costs by 20% and construction time by 30%, while AI-powered systems can reduce accident rates by up to 25%. In Malaysia, the Construction Industry Development Board (CIDB) promotes Industry 4.0 strategies, while studies highlight the role of cloud computing in enhancing small project sustainability through improved cost, quality, and communication management. In view of that, integrating emerging technologies within the construction sector addresses pressing environmental issues, reduces resource consumption, and supports global efforts to mitigate greenhouse gas emissions and promote sustainable development.

Besides, in alignment with the Malaysian Construction 4.0 Strategic Plan (2021-2025), which emphasizes the adoption of digital technologies such as BIM, IoT and robotics to enhance productivity, quality and sustainability, this study explores how emerging technologies can drive sustainable practices in the local construction sector, understanding the key drivers and barriers to technology adoption is critical for strategic alignment and successful policy implementation. This study also supports the goals outlined in the Twelfth Malaysia Plan (2021-2025), which prioritizes sustainable development, digital transformation, and a low-carbon economy. As outlined under Theme 3 of the 12MP “Advancing Sustainability”, the adoption of smart and resource-efficient technologies in construction is key to achieving sustainability targets. Therefore, evaluating the industry’s readiness and key adoption factors is timely and policy relevant.

The construction industry faces substantial challenges in achieving sustainability due to its reliance on traditional methods that consume non-renewable resources, generate significant waste, and contribute heavily to greenhouse gas emissions. According to the International Energy Agency, the building sector accounted for 36% of global final energy consumption and 39% of energy-related CO_2 emissions in 2018. Construction activities also produce dust and noise, negatively affecting public health, with prolonged exposure linked to respiratory diseases (Isah, 2019). Waste generation is another pressing issue; construction waste contributes to 40% of Canada’s solid waste and 65% in Hong Kong, with inadequate waste management practices exacerbating environmental degradation (Abubakar et al., 2022).

To address these challenges, global and national efforts are increasingly focusing on integrating emerging technologies to enhance sustainability. In Malaysia, the Construction Industry Development Board (CIDB) and the government are promoting Industry 4.0 technologies—such as Building Information Modelling (BIM), Internet of Things (IoT), 3D printing, and prefabrication—to improve productivity, resource efficiency, and environmental performance. National policies like the Construction Industry Transformation Programme (CITP) 2016-2020 and Industry4WRD underscore the importance of digital transformation for sustainable economic growth (MITI, 2018). While studies have explored advancements like Industry 6.0 and smart facilities management (Zhan et al., 2023), there remains a research gap regarding the opportunities, drivers, and challenges of adopting emerging technologies for sustainable construction.

Harnessing innovations like IoT-enabled smart buildings can lead to up to 30% energy savings, while 3D printing can reduce material waste by 50% and shorten project durations by 30% (Adebowale and Agumba, 2024). Despite growing interest in sustainability and technological advancements, research remains limited on the adoption of emerging technologies to foster a sustainable construction industry. There is a gap in understanding the key drivers and underlying factors influencing their implementation. Therefore, this research aims to address this gap by assessing the drivers of using emerging technologies to create a sustainable construction and uncover the associated underlying factors that are relevant to the Malaysian construction industry.

II. LITERATURE REVIEW

Sustainability in construction extends beyond environmental concerns to encompass economic, social, and technical dimensions. Mensah (2019) defines sustainability as a balanced approach that ensures the preservation of natural resources while supporting long-term ecological and economic stability. Similarly, Mavi et al. (2021) emphasize that sustainable construction must integrate environmental responsibility with economic viability, social well-being, and technical innovation. This holistic perspective highlights the necessity for construction practices that reduce environmental impact while maintaining cost efficiency, ensuring worker safety, and utilizing durable, high-performance materials.

The adoption of emerging technologies is revolutionizing the construction industry, enhancing efficiency, reducing waste, and lowering carbon emissions. Advanced tools such as Building Information Modeling (BIM), 3D printing, smart building systems, and automation are critical to achieving sustainability goals. Shen, Zhang and Zhang (2017) note that these technologies improve resource management, reduce project timelines, and support energy-efficient construction processes. Early integration during planning and design phases is essential, as it allows sustainability principles to be embedded throughout the project lifecycle.

2.1 Drivers of Emerging Technologies in Sustainable Construction

Table 1 shows the five categories of drivers of using emerging technologies in construction. The widespread adoption of emerging technologies in the construction industry is influenced by several key drivers, including regulatory and market influences, economic and competitive factors, technological advancements, environmental and resource considerations, and strategic motivations. These factors are identified from the comprehensive review of preview studies and each of them plays a critical role in encouraging the industry to transition toward more sustainable and efficient construction practices.

Table 1.0 Five Categories of Drivers of Emerging Technologies in Construction

Regulatory and Market Influences	Green Certifications and Standards
	Regulatory Requirements
	Market Demand
	Public and Stakeholder Pressure
	Global Environmental Initiatives
	Carbon Pricing and Emissions Trading System (ETS)
Corporate and Organizational Factors	Corporate Social Responsibility (CSR)
	Risk Management
	Client and Investor Expectations
	Reduction of Operational Costs
Technological and Innovation Approach	Technological Integration and Smart System
	Innovation in Material Science
	Technological Advancements
Resource and Environmental Considerations	Urbanization and Sustainable City Planning
	Resource Scarcity
	Energy Efficiency Goals
	Environmental Awareness
Competitive and Strategic Motivations	Educational and Training Programs
	Health and Well-being Concerns
	Competitive Advantage

2.1.1 Regulatory and Market Influences

Government policies and industry regulations play a crucial role in encouraging the adoption of sustainable technologies. Green certifications such as LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method) set strict environmental and energy efficiency standards, pushing companies to integrate innovative technologies in their projects (Plakantonaki *et al.*, 2023). Additionally, government incentives such as tax rebates, grants, and subsidies make sustainable construction more financially viable. Carbon pricing and emissions trading systems (ETS) further drive companies to adopt low-carbon technologies by imposing costs on excessive emissions, compelling industries to shift toward energy-efficient solutions (Yu *et al.*, 2018).

The market demand for sustainable construction has also grown significantly, with clients, investors, and end-users prioritizing eco-friendly and energy-efficient buildings. As consumers become more environmentally conscious, companies integrating BIM, smart building systems, and renewable energy solutions gain a competitive edge (Salzano *et al.*, 2024). Public and stakeholder pressure, including advocacy from environmental groups, regulatory bodies, and financial institutions, further accelerates the push toward sustainable practices.

2.1.2 Economic and Competitive Factors

Adopting emerging technologies in construction offers long-term cost savings and enhanced operational efficiency. Energy-efficient buildings, smart grids, and prefabrication techniques reduce material waste, optimize resource use, and lower lifecycle costs (Alotaibi *et al.*, 2020). Automation and robotics improve construction speed and precision, minimizing rework and labor costs while increasing productivity. Despite high initial investments, these technologies provide significant return on investment (ROI) by lowering maintenance costs and extending the lifespan of buildings.

Additionally, sustainability-driven construction companies benefit from stronger investor confidence and financial backing. Many investors prioritize projects that align with Environmental, Social, and Governance (ESG) criteria, leading to increased funding opportunities for firms that integrate renewable energy, energy storage systems, and low-carbon construction materials (Zhang, Ma and Liu, 2020).

2.1.3 Technological Advancements and Innovation

Rapid advancements in Artificial Intelligence (AI), the Internet of Things (IoT), and digital twins have revolutionized construction by enabling real-time monitoring, predictive maintenance, and optimized project management. BIM has evolved beyond 3D modeling to integrate with IoT and cloud computing, facilitating collaborative, data-driven decision-making that improves construction efficiency and sustainability (Zhang *et al.*, 2023). Robotics and 3D printing have further streamlined construction by reducing material waste and enabling the use of sustainable, recyclable materials. Additionally, material science innovations have led to the development of self-healing concrete, low-carbon cement, and bio-based composites, reducing the environmental impact of traditional building materials. These advancements align with the circular economy, where materials are repurposed and reused, minimizing construction waste (Ferrara, La Noce and Sciuto, 2023).

2.1.4 Environmental and Resource Considerations

The depletion of natural resources and rising environmental concerns have accelerated the adoption of sustainable construction technologies. Circular economy principles, such as recycling construction waste, repurposing materials, and reducing energy consumption, have become essential in modern construction practices (Opoku and Lee, 2022). Water-efficient technologies, such as smart irrigation systems and greywater recycling, are being integrated into projects to optimize water use and address water scarcity issues. Energy efficiency has also become a priority, with smart building technologies, renewable energy integration, and hydrogen-. powered construction equipment emerging as viable solutions to reduce the carbon footprint of the construction industry (Yap and McLellan, 2023). The shift toward hybrid renewable energy systems, including solar, wind, and energy storage solutions, ensures reliable and sustainable power sources for construction projects.

2.1.5 Competitive and Strategic Motivations

The adoption of emerging technologies provides a competitive advantage by improving efficiency, reducing costs, and attracting environmentally conscious clients and investors. Technologies such as BIM, AI-driven predictive maintenance, and drones streamline operations, enhance project accuracy, and minimize labour expenses, making firms more competitive in securing contracts (Liu et al., 2020). Additionally, 3D printing and automation reduce material waste and construction timelines, allowing companies to deliver high-quality, sustainable projects while differentiating themselves in the market.

Beyond competitiveness, health and safety concerns drive the integration of wearable smart PPE, IoT-enabled monitoring systems, and BIM-based risk assessments, which help prevent workplace hazards and improve safety standards (Oesterreich and Teuteberg, 2016). Virtual and augmented reality (VR/AR) further enhance training by allowing workers to simulate hazardous situations in a controlled environment (Kassem, Benomran and Teizer, 2017). To support industry-wide adoption, initiatives such as MIEEIP and SEDA Malaysia's training programs focus on equipping professionals with the necessary skills for implementing sustainable, energy-efficient construction practices, ensuring a future-ready workplace (SEDA, 2017).

III. METHODOLOGY

This study adopted a pragmatic paradigm using the quantitative research approach, and the research variables were obtained from deductive reasoning by reviewing past studies. Non-probability techniques of purposive and convenience sampling with snowball sampling are used in this study. A structured questionnaire survey is used to collect data from construction practitioners, including developers, consultants and contractors, to assess their perspectives on the adoption of emerging technologies in sustainable construction. The study focuses on professionals in Klang Valley, Malaysia as it is a major hub for construction and urban development. The key drivers of adoption using a five-point Likert scale (1=no influence to 5=very strong influence), ensuring structured analysis while limiting qualitative input. This structured approach provides valuable insights into the drivers that influence the adoption of emerging technologies in construction. Figure 1.0 illustrates the framework of the research.

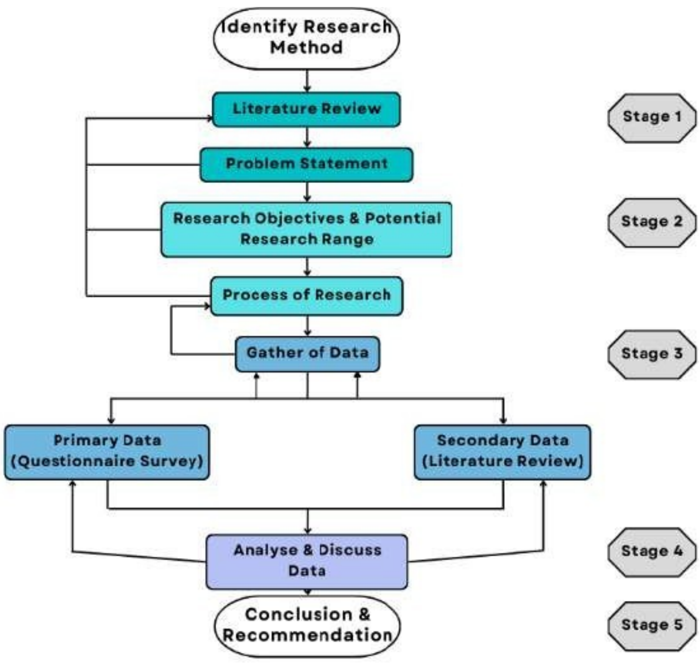

Figure 1.0 Framework of the Research

3.2 Background of Respondents

Table 2 indicates the demographic profile of the 120 respondents. A pilot study was conducted with 30 respondents, including eight developers, ten contractors, and twelve consultants. The pilot test was conducted before full-scale data collection to ensure the reliability, clarity, and relevance of the questionnaire items. Pilot testing enhances the validity of the instrument and reduces the risk of non-response or misinterpretation in the main study (Pallant, 2020). According to Grace-Martin (2024), a sample size of 100 is adequate for meaningful statistical analyses, but more is better. The study has collected a total of 120 respondents.

Table 2: Demographic Profile of Respondents

Profile	Description	Frequency	Percentage (%)
Construction Roles	Client	41	34.2
	Contractor	40	33.3
	Consultant	39	32.5
Industry background	Quantity Surveyor	48	40.0
	Architect	18	15.0
	M&E Engineer	19	15.8
	C&S Engineer	17	14.2
	Project/Construction Management	18	15.0
Types of Organization	Public Sector	45	37.5
	Private Sector	75	62.5
Academic qualification	Diploma	6	5.0
	Degree	91	75.8
	Postgraduate Degree	23	19.2
Working experience	Less than 5 years	67	55.8
	5 – 10 years	29	24.2
	11 – 20 years	17	14.2
	More than 20 years	7	5.8
Primary Operate Region	Klang Valley	81	56.3
	Northen Region	17	11.8
	Southern Region	27	18.8
	East Coast	8	5.6
	Sabah	5	3.5
	Sarawak	6	4.2
Types of Projects Involved	Residential	71	37.6
	Commercial	55	29.1
	Industrial	38	20.1
	Infrastructure	13	6.9
	Environmental	12	6.3
Experience with sustainable construction technologies	Unfamiliar with these technologies	7	5.8
	Heard of these technologies	43	35.8
	Have basic experience using these technologies	50	41.7
	Proficient in using these technologies	16	13.3
	Expert and actively using these technologies	4	3.3

IV. RESULTS AND DISCUSSIONS

Table 3 in the Appendix summarizes the results for mean score and standard deviation. The mean score represents the average level of agreement or importance assigned to each strategy by respondents. In this case, the top five strategies (D10, D2, D9, D13, D3) all have mean scores above 4.0, indicating that these strategies are perceived as highly viable by stakeholders in construction projects. A higher mean score suggests a strong preference or recognition of a strategy's significance, while a lower standard deviation (SD) indicates consistency in responses, meaning that most participants agreed on these rankings. The table results indicate that regulatory requirements (D2) and reduction of operational costs (D10) are the highest-rated factors (mean = 4.23), highlighting that compliance with policies and financial efficiency are the primary concerns in sustainable construction. Client and investor expectations (D9) (mean = 4.19) reinforce the importance of sustainability-driven investments, while technological integration (D13) (mean = 4.16) and market demand (D3) (mean = 4.10) emphasize the growing role of innovation and industry trends in driving technology adoption.

The Kruskal-Wallis H test is a non-parametric statistical test used to determine if there are significant differences between three or more independent groups on a particular variable (Field, 2018). It is an alternative to one-way ANOVA when data is not normally distributed (Pallant, 2020). The Chi-square (X^2) and p-value determine whether there are statistically significant differences between client, contractor and consultant responses. Based on the result shown in Table 2, all p-values (>0.05) indicate no significant differences in rankings among clients, contractors and consultants, meaning stakeholders share similar views on these strategies. This suggests that industry-wide policies and strategies can be standardized, making it easier for policymakers and construction firms to implement unified sustainability initiatives. These findings reinforce the need for technology-driven efficiency, financial viability, and regulatory compliance, aligning with previous studies that emphasize BIM, AI, and IoT adoption (Hair et al., 2019) and the role of market-driven sustainability investments (Shen et al., 2017). The results confirm that sustainability strategies should focus on aligning regulatory policies, investment incentives, and technological advancements to ensure successful adoption in the construction industry.

Factor analysis is a statistical method used to identify underlying relationships between variables by grouping them into factors based on shared variance (Hair et al., 2019). **Table 4** summarizes the result of factor analysis. The Kaiser-Meyer-Olkin (KMO) measure of 0.885 indicates excellent sampling adequacy, suggesting that the dataset is well-suited for factor analysis. Bartlett's test of sphericity (X^2 = 998.973, $p < 0.001$) confirms that correlations among variables are sufficient for structure detection, rejecting the null hypothesis of an identity matrix (Field, 2018). These results justify proceeding with factor analysis to uncover latent constructs, aiding in data reduction and interpretation.

Table 4: Results of KMO and Bartlett's Tests

Parameter	Value
Kaiser-Meyer-Olkin measure of sampling adequacy	0.885
Bartlett's test of sphericity	
Approximate chi-square value	988.973
Degree of freedom	190
Significance	<.001

The factor analysis extracted four key factors: (1) Regulatory and Environmental Factors, (2) Technological and Innovation Factors, (3) Economic and Market Factors, (4) Social and Sustainability Factors, explaining 57.38% of the total variance as shown in **Table 5**.

Table 5: Total Variance Explained

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	7.740	38.699	38.669
2	1.415	7.073	45.772
3	1.293	6.466	52.238
4	1.028	5.139	57.377

4.1 Regulatory and Environmental Factors

This study corroborates the findings of Zhang et al. (2023), who highlighted the role of policy-driven sustainability adoption. However, this study introduces stakeholder pressure—including public expectations and investor influence—as a new and significant driver. Unlike previous studies that focused primarily on top-down regulations, this research highlights the increasing role of market-driven and societal expectations in shaping sustainability initiatives.

4.2 Technological and Innovation Factors

The results align with the findings of Hair et al. (2019), which underscored the importance of Building Information Modelling (BIM), Artificial Intelligence (AI), and digital twins in improving efficiency and sustainability in construction. However, while prior studies primarily focused on process optimization through AI and automation, this study broadens the scope by incorporating material science advancements, such as self-healing concrete and sustainable composites, as key enablers of construction sustainability. This distinction underscores the integration of smart technologies with sustainable materials as a crucial strategy for reducing environmental impact.

4.3 Economic and Market Factors

Consistent with the findings of Alotaibi et al. (2020), this study emphasised financial efficiency and project cost savings as key drivers of technology adoption. However, this study extends the discussion by linking economic efficiency to competitive positioning, illustrating how companies that adopt emerging technologies gain a strategic advantage in the industry. Unlike previous research that primarily focused on cost savings and risk mitigation, this study highlights the long-term economic benefits of sustainability-driven innovations, reinforcing the idea that early adopters of technology will have stronger market positioning, who emphasized financial efficiency and project cost savings as key drivers of technology adoption.

4.4 Social and Sustainability Factors

The results align with Plakantonaki et al. (2023), who recognized the importance of corporate social responsibility in sustainability efforts. However, this study expands on prior findings by emphasizing the need for workforce training and upskilling to ensure the effective implementation of emerging technologies. While previous studies primarily focused on policy incentives and market demand, this research highlights the role of human capital in driving technology adoption, reinforcing the importance of education and skills development in achieving long-term sustainability goals.

Hence, education and training programs emerged as a significant factor, indicating the growing need for technical skills development to support sustainable technology adoption. Also, green urban planning is gaining importance as a sustainability driver, aligning with recent global initiatives for smart cities and eco-friendly infrastructure while standardised regulations and policies continue to play a crucial role in ensuring the widespread adoption of sustainable practices, consistent across multiple studies.

CONCLUSION

In conclusion, this study is crucial due to the increasing need for sustainable construction practices and the role of emerging technologies in addressing environmental, economic, and social challenges. The findings highlight four key factors influencing technology adoption: regulatory and environmental factors, technological and innovation factors, economic and market factors, and social and sustainability factors, all of which shape the industry's transition towards sustainability. The study contributes to theory by expanding the understanding of how innovation aligns with sustainability goals, while in practice, it offers insights for policymakers and industry leaders to enhance regulations, workforce training, and investment strategies. In Malaysia, the findings support Industry 4.0 initiatives by encouraging smart construction adoption, while internationally, the study informs global green building standards and digital transformation strategies. However, the study is limited by its focus on Malaysia and its reliance on a survey-based methodology, which may not fully capture the diverse perspectives of the global construction industry. Future studies should consider cross-country analyses and real-world case studies to enhance the generalisability and applicability of the findings. Figure 2.0 illustrates the technology impact on sustainable construction

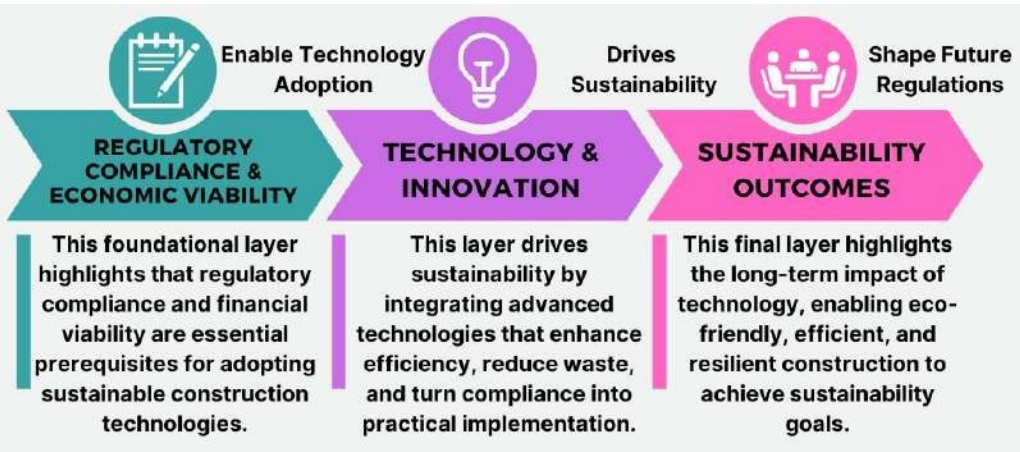

Figure 2.0 Technology Impact on Sustainable Construction

REFERENCES

Abubakar, I. R., Maniruzzaman, K. M., Dano, U. L., AlShihri, F. S., AlShammari, M. S., Ahmed, S. M. S., Al-Gehlani, W. A. G., & Alrawaf, T. I. (2022). Environmental Sustainability Impacts of Solid Waste Management Practices in the Global South. *International Journal of Environmental Research and Public Health*, *19*(19), 12717. https://doi.org/10.3390/ijerph191912717

Adebowale, O. J., & Agumba, J. N. (2022). Applications of augmented reality for construction productivity improvement: a systematic review. *Smart and Sustainable Built Environment*, *13*(3). https://doi.org/10.1108/sasbe-06-2022-0128

Adlina. (2025). *Pelan Strategik Pembinaan 4.0 (2021-2025) Mengubah Permainan Industri | CIDB HQ*. CIDB HQ. https://www.cidb.gov.my/eng/construction-4-0-strategic-plan-2021-2025-alters-the-industry-game/

Ahsan Waqar, Krzysztof Skrzypkowski, Hamad Almujibah, Krzysztof Zagórski, Muhammad Basit Khan, Zagórska, A., & Omrane Benjeddou. (2023). Success of Implementing Cloud Computing for Smart Development in Small Construction Projects. *Success of Implementing Cloud Computing for Smart Development in Small Construction Projects*, *13*(9), 5713–5713. https://doi.org/10.3390/app13095713

Alotaibi, I., Abido, M. A., Khalid, M., & Savkin, A. V. (2020). A Comprehensive Review of Recent Advances in Smart Grids: A Sustainable Future with Renewable Energy Resources. *Energies*, *13*(23), 6269. https://doi.org/10.3390/en13236269

Bademosi, F. M., & Issa, R. R. A. (2022). Automation and Robotics Technologies Deployment Trends in Construction. *Automation and Robotics in the Architecture, Engineering, and Construction Industry*, 1–30. https://doi.org/10.1007/978-3-030-77163-8_1

Babones, S. (2015). Interpretive quantitative methods for the social sciences. *Sociology*, *50*(3), 453–469. https://doi.org/10.1177/0038038515583637

Camara, M., Jamil, N. R., & Abdullah, A. F. B. (2019). Impact of land uses on water quality in Malaysia: a review. *Ecological Processes*, *8*(1). https://doi.org/10.1186/s13717-019-0164-x

Christoforidis, T., & Katrakilidis, C. (2021). Does Foreign Direct Investment Matter for Environmental Degradation? Empirical Evidence from Central–Eastern European Countries. *Journal of the Knowledge Economy*. https://doi.org/10.1007/s13132-021-00820-y

Ferrara, P. L., La Noce, M., & Sciuto, G. (2023). Sustainability of Green Building Materials: A Scientometric Review of Geopolymers from a Circular
Economy Perspective. *Sustainability*, *15*(22), 16047. https://doi.org/10.3390/su152216047

Field, A. (2018). *Discovering Statistics Using IBM SPSS Statistics*.
http://repo.darmajaya.ac.id/5678/1/Discovering%20Statistics%20Using%20IBM%20SPSS%20Statistics%20%28%20PDFDrive%20%29.pdf

Grace-Martin, K. (2024, September 23). *How Big of a Sample Size do you need for Factor Analysis?* Medium. https://medium.com/@kgm_52135/how-big-of-a-sample-size-do-you-need-for-factor-analysis-fb61826aa059

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E. (2019). Multivariate Data Analysis. United Kingdom: Cengage.

Hire, S., Sandbhor, S., & Ruikar, K. (2021). Bibliometric Survey for Adoption of Building Information Modeling (BIM) in Construction Industry– A Safety Perspective. *Archives of Computational Methods in Engineering*. springer. https://doi.org/10.1007/s11831-021-09584-9

Hou, F., Su, H., Li, Y., Qian, W., Xiao, J., & Guo, S. (2021). The Impact of Foreign Direct Investment on China's Carbon Emissions. *Sustainability*, *13*(21), 11911. https://doi.org/10.3390/su132111911

Isah, H. (2019). Health And Safety Issues In the Nigerian Construction Industries: Prevention And Mitigation. *The European Proceedings of Multidisciplinary Sciences*. https://doi.org/10.15405/epms.2019.12.74

Kassem, M., Benomran, L., & Teizer, J. (2017). Virtual environments for safety learning in construction and engineering: seeking evidence and identifying gaps for future research. *Visualization in Engineering*, *5*(1). https://doi.org/10.1186/s40327-017-0054-1

Liu, Z.-J., Pypłacz, P., Ermakova, M., & Konev, P. (2020). Sustainable Construction as a Competitive Advantage. *Sustainability*, *12*(15), 5946. MDPI. https://doi.org/10.3390/su12155946

Mavi, R. K., Gengatharen, D., Mavi, N. K., Hughes, R., Campbell, A., & Yates, R. (2021). Sustainability in Construction Projects: A Systematic Literature Review. *Sustainability*, *13*(4), 1932. MDPI. https://doi.org/10.3390/su13041932

Mensah, J. (2019). Sustainable development: Meaning, history, principles, pillars, and Implications for Human action: Literature Review. *Cogent Social Sciences*, *5*(1), 1–21. Tandfonline.
https://doi.org/10.1080/23311886.2019.1653531

MITI (2018) 'Industry4WRD Readiness Assessment', *Ministry of International Trade and Industry* [Preprint].

Oesterreich, T. D., & Teuteberg, F. (2016). Understanding the Implications of Digitisation and Automation in the Context of Industry 4.0: a Triangulation Approach and Elements of a Research Agenda for the Construction Industry. *Computers in Industry*, *83*, 121–139. https://doi.org/10.1016/j.compind.2016.09.006

Opoku, D.-G. J., Agyekum, K., & Ayarkwa, J. (2019). Drivers of environmental sustainability of construction projects: a thematic analysis of verbatim comments from built environment consultants. *International Journal of Construction Management*, *22*(6), 1–9. https://doi.org/10.1080/15623599.2019.1678865

Pallant, J. (2020). SPSS survival manual: a step by step guide to data analysis using IBM SPSS. *Australian and New Zealand Journal of Public Health*, *37*(6), 597–598. https://doi.org/10.1111/1753-6405.12166

Plakantonaki, S., Kiskira, K., Zacharopoulos, N., Chronis, I., Coelho, F., Togiani, A., Kalkanis, K., & Priniotakis, G. (2023). A Review of Sustainability Standards and Ecolabeling in the Textile Industry. *Sustainability*, *15*(15), 11589. https://doi.org/10.3390/su151511589

Sanogo Boubacar, Francis Atta Sarpong, & Nyantakyi, G. (2024). Shades of sustainability: decoding the impact of foreign direct investment on CO2 emissions in Africa's growth trajectory. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-024-04656-9

Salzano, A., Cascone, S., Zitiello, E. P., & Nicolella, M. (2024). Construction Safety and Efficiency: Integrating Building Information Modeling into Risk Management and Project Execution. *Sustainability*, *16*(10), 4094. https://doi.org/10.3390/su16104094

SEDA (2017) 'Sustainable Energy Development Authority Malaysia (SEDA)', *Seda* [Preprint].

Shen, L., Zhang, Z., & Zhang, X. (2017). Key factors affecting green procurement in real estate development: a China study. *Journal of Cleaner Production*, *153*, 372–383. https://doi.org/10.1016/j.jclepro.2016.02.021

Twelfth Malaysia Plan (2021-2025). A Prosperous, Inclusive, Sustainable Malaysia. RMK12. https://rmke12.ekonomi.gov.my/file/download/2021092722_twelfth_malaysia_plan.pdf?path=fileUpload/2021/09/2021092722_twelfth_malaysia_plan.pdf&name=Twelfth%20Plan%20Document.pdf

Yap, J., & McLellan, B. (2023). A Historical Analysis of Hydrogen Economy Research, Development, and Expectations, 1972 to 2020. *Environments*, *10*(1), 11. https://doi.org/10.3390/environments10010011

Yu, M., Zhu, F., Yang, X., Wang, L., & Sun, X. (2018). Integrating Sustainability into Construction Engineering Projects: Perspective of Sustainable Project Planning. *Sustainability*, *10*(3), 784. https://doi.org/10.3390/su10030784

Zakaria, S. A. S., & Singh, A. K. M. (2023). Environmental Issues and Sustainability in Malaysia – A Community Perspective. *1st International Postgraduate Conference on Ocean Engineering Technology and Informatics2021 (IPCOETI 2021)*. https://doi.org/10.1063/5.0110452

Zhan, H., Hwang, B.-G., Zhu, H., & Swee Hoon Ang. (2023). Towards a sustainable built environment industry in Singapore: Drivers, barriers, and strategies in the adoption of smart facilities management. *Journal of Cleaner Production*, 138726–138726. https://doi.org/10.1016/j.jclepro.2023.138726

Zhang, B., Ma, L., & Liu, Z. (2020). Literature Trend Identification of Sustainable Technology Innovation: A Bibliometric Study Based on Co-Citation and Main Path Analysis. *Sustainability*, *12*(20), 8664. https://doi.org/10.3390/su12208664

Zhang, J., Zhu, Z., Liu, H., Zuo, J., Ke, Y., Philbin, S. P., Zhou, Z., Feng, Y., & Ni, Q. (2023). System Framework for Digital Monitoring of the Construction of Asphalt Concrete Pavement Based on IoT, BeiDou Navigation System, and 5G Technology. *Buildings*, *13*(2), 503–503. https://doi.org/10.3390/buildings13020503

APPENDIX 1 – Mean Score and Ranking

Table 3: Mean Scores and Ranking of Viable Strategies Surveyed

Ref	Overall (N=120)			Client (N=41)			Contractor (N=40)			Consultant (N=39)				
	Mean	SD	Mean	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	X^2	P-value
D10	4.23	0.719	1	4.22	0.852	1	4.27	0.716	1	4.21	0.570	4	0.558	0.757
D2	4.23	0.727	2	4.17	0.629	2	4.25	0.840	2	4.26	0.715	1	0.959	0.619
D9	4.19	0.714	3	4.15	0.760	3	4.20	0.791	3	4.23	0.583	3	0.134	0.935
D13	4.16	0.756	4	4.07	0.721	5	4.15	0.834	4	4.26	0.715	2	1.398	0.497
D3	4.10	0.782	5	4.12	0.748	4	4.13	0.853	5	4.05	0.759	5	0.393	0.822

D2 – Regulatory Requirements
D3 – Market Demand for Sustainable Construction
D9 – Client and Investor Expectations
D10 – Reduction of Operational Costs
D13 – Technological Integration and Smart Systems

UNIVERSITI TEKNOLOGI MARA | Cawangan Perak

eISBN 978-629-94789-0-4

9 786299 478904

(online)