e-ISSN: 2550-1569

Available online at
https://myjms.mohe.gov.my/index.php/IJSMS

International Journal of Service Management and Sustainability
10(1) 2025, 39 – 50.

International Journal of Service Management and Sustainability (IJSMSust)

Innovative Waste Management in the Malaysian Construction Industry: Challenges and Strategic Approaches

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ARTICLE INFO

Article history:
Received 13 November 2024
Revised 4 March 2025
Accepted 11 March 2025
Online first
Published 31 March 2025

Keywords:
innovative
waste management
challenges
strategic approaches
the Malaysian construction industry

DOI: 10.24191/ijsms.v10i1.24215

Citation in APA:
Marhani, M. A., Abdul Rahim, M. H., Raja Muhammad Rooshdi, R. R., Ismail, N. A. A., & Sahamir, S. R. (2025). Innovative waste management in the Malaysian construction industry: challenges and strategic approaches. *International Journal of Service Management and Sustainability, 10*(1), 39 – 50.

ABSTRACT

The construction industry is one of the greatest generators of waste to deal with; therefore, effective waste management is critical. This process entails the collection, transmission, disposal, and recycling of various wastes produced by human activities. Industry practitioners must educate themselves about modern and creative waste management technologies to significantly reduce construction waste. This manuscript aims to investigate and improve innovative waste management strategies in the Malaysian construction industry. The goals are to identify the challenges to their implementation and to encourage the adoption of these novel systems among industry practitioners. The study adopts a quantitative methodology, with data collected through an online questionnaire survey of G7 contractors registered with the Construction Industry Development Board Malaysia (CIDB) in the Klang Valley area. Out of the 155 targeted respondents, 73 completed the survey, for a 47% response rate. The findings highlight the most widely used innovative waste management solutions in Malaysia's construction industry, as well as the challenges to their acceptance and the most effective techniques for encouraging their use. Key obstacles include a lack of incentives and financial limits. By addressing these difficulties and supporting sustainable practices, the study highlights the significance of innovative waste management systems for improving sustainability and efficiency in Malaysia's construction industry.

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1.0 INTRODUCTION

The construction industry is a major contributor to global economic growth but also a significant producer of waste, accounting for approximately 35% of the world's total waste generation (Zhang et al., 2019). In Malaysia, the Construction Industry Development Board (CIDB) reported that industry-generated projects were valued at MYR 110 billion in 2013-a figure that continues to rise alongside urbanisation and infrastructure development (Asnor et al., 2022). Consequently, the management of construction waste has emerged as a critical environmental and economic challenge.

Current studies have explored various waste management practices, emphasising the 3R principles of "reduce, reuse, and recycle" (Ma et al., 2022). Even though technology has improved, innovative waste management systems (WMS) are still not widely used because of problems like high start-up costs, weak government enforcement, and a lack of industry awareness (Tambovceva et al., 2020). While smart waste bins, waste tracking systems, and solar-powered compactors have shown potential to enhance sustainability, their adoption within the Malaysian construction industry has been limited.

A key gap in research lies in understanding the effectiveness of these innovations and identifying the challenges preventing their widespread implementation. Studies have highlighted the lack of financial incentives and regulatory support as primary deterrents (Mohammed et al., 2022). Furthermore, knowledge and skills gaps among industry practitioners hinder the effective execution of sustainable waste management strategies (Tian et al., 2018). Addressing these gaps is crucial to developing a circular economy framework that minimises environmental impacts while optimising resource efficiency.

The study's goals are to fill in these gaps by looking at the latest innovations in managing construction waste, figuring out the biggest challenges by putting them into practice, and suggesting ways to get more people in the industry to use them. By synthesising existing knowledge with empirical data, this research seeks to contribute practical solutions that support Malaysia's sustainability goals and align with global best practices. Filling these research gaps will not only improve waste management efficiency but also foster environmental responsibility within the construction sector.

2.0 LITERATURE REVIEW

2.1 Innovative Waste Management

The construction industry is one of the largest contributors to global waste generation, with significant environmental and economic implications. Traditional waste management systems struggle to cope with increasing waste volumes, prompting the need for innovative solutions. Innovations in waste management integrate technology, sustainability principles, and regulatory measures to enhance efficiency and reduce environmental impact (Tambovceva et al., 2020).

Recent advancements in waste management technology include smart waste bins equipped with Internet of Things (IoT) sensors, waste tracking systems, and artificial intelligence (AI)-driven recycling processes. These innovations facilitate real-time monitoring and optimise waste collection, reducing landfill dependency and improving resource recovery (Putinceva et al., 2020). The integration of Building Information Modelling (BIM) in construction waste management has further improved material planning, reducing waste at source (Zoghi & Kim, 2020). Additionally, prefabrication and modular construction techniques have been widely adopted to minimise on-site waste generation (Han et al., 2021).

Government policies play a crucial role in promoting innovative waste management practices. Financial incentives, such as tax benefits and subsidies, have been identified as effective strategies to encourage adoption (Ghaffar et al., 2020). Countries with well-established waste management regulations have successfully implemented circular economic frameworks that emphasise recycling and reuse (Al-

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Otaibi et al., 2022). However, in Malaysia, the lack of robust policies and inadequate financial support remain significant challenges (Umar et al., 2021).

The existing literature highlights the need for further research on overcoming financial and regulatory challenges to implementing innovative waste management systems. Understanding the cost-benefit analysis of these technologies and assessing their long-term sustainability impact can provide valuable insights for policymakers and industry practitioners (Ma et al., 2022). By addressing these research gaps, the construction industry can transition towards more sustainable waste management practices, reducing its ecological footprint while improving efficiency.

2.2 The Challenges in Implementing Innovative Waste Management

The adoption of innovative waste management systems is essential for achieving sustainability in the construction industry. However, despite technological advancements, the implementation of these systems faces significant challenges. These challenges include lack of knowledge and skills, inadequate policies and financial incentives, high initial costs, and workplace safety concerns (Zhang et al., 2019).

A major challenge to implementing innovative waste management systems is the lack of knowledge and expertise among industry practitioners. The construction industry in Malaysia generates various waste materials, including asphalt, metals, wood, and plastic, yet the workforce often lacks the necessary skills to implement advanced waste management strategies effectively (Wong & Gray, 2019). This knowledge gap hinders the adoption of sustainable waste management practices, necessitating the development of training programs and educational initiatives (Mohammed et al., 2022).

Another key challenge is the absence of effective regulatory policies and financial incentives to promote the adoption of innovative waste management solutions. Inefficient policy enforcement has led to inadequate waste management practices, while financial constraints discourage companies from investing in advanced waste management technologies (Ghaffar et al., 2020). Countries with robust regulatory frameworks have successfully implemented circular economy strategies, but Malaysia still lacks the necessary support structures (Al-Otaibi et al., 2022). A comprehensive approach involving both government regulations and financial incentives is essential to encourage sustainable practices.

The high upfront costs associated with adopting new waste management technologies act as a significant deterrent, especially for small and medium-sized enterprises. These costs include investment in smart waste bins, waste tracking systems, and solar-powered compactors, in addition to the training required for employees to operate these systems efficiently (Huang et al., 2018). While these technologies prove cost-effective in the long run, the initial capital investment remains a challenge for many firms (Mohammed et al., 2022).

Safety risks associated with implementing new waste management technologies also hinder their adoption. The integration of automated waste sorting systems and smart bins may introduce hazards that require additional safety protocols and training (Zerguine et al., 2018). Concerns over vandalism and theft of high-value equipment further exacerbate the issue, necessitating enhanced security measures (Oke et al., 2023).

Current studies highlight the need for further research on financial models, policy frameworks, and knowledge dissemination strategies to overcome these challenges. Filling in these gaps through real-world research and industry cooperation will make it easier to implement new waste management ideas, which will ensure the construction industry's long-term viability (Ma et al., 2022).

2.3 Recommendations for Encouraging Innovative Waste Management

The construction industry significantly contributes to global waste generation, necessitating innovative waste management solutions to enhance sustainability. Despite the availability of advanced technologies, their adoption remains limited due to several challenges, including financial constraints, lack

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of awareness, and regulatory gaps (Ghaffar et al., 2020). This section presents key recommendations to encourage the adoption of innovative waste management systems.

A crucial step in promoting innovation in waste management is through education and knowledge dissemination. Establishing partnerships between technology providers, educational institutions, and industry stakeholders can facilitate targeted training programs (Wong & Gray, 2019). Workshops, seminars, and case study-based learning can bridge knowledge gaps, demonstrating the practical benefits of advanced waste management practices (Mohammed et al., 2022). Encouraging industry-wide certification programs can further enhance practitioners' competencies in adopting innovative technologies.

Implementing new waste management systems necessitates workforce training to mitigate safety risks. Utilising immersive learning techniques such as virtual reality (VR) and augmented reality (AR) can provide hands-on safety training, reducing risks associated with handling new technologies (Ishak et al., 2022). Periodic refresher courses can ensure sustained compliance with safety standards and foster a culture of safety awareness within organisations (Zerguine et al., 2018).

The high initial cost of adopting innovative waste management solutions remains a significant challenge. Governments and financial institutions should offer grants, subsidies, and low-interest loans to alleviate financial burdens (Huang et al., 2018). Creative financing options such as leasing models, pay-as-you-save schemes, and green bonds can also provide affordable investment opportunities for businesses (Mohammed et al., 2022). Establishing green investment banks can further facilitate financial support for projects demonstrating environmental sustainability (Ghaffar et al., 2020).

Regulatory frameworks play a pivotal role in encouraging waste management innovation. Governments should standardise and certify new waste management technologies, ensuring compliance with environmental and safety standards (Noiki et al., 2021). Public procurement policies prioritising sustainable waste management solutions in government projects can create a market for innovation (Al-Otaibi et al., 2022). Additionally, streamlined approval processes for green technology projects can expedite adoption rates (Mohammed et al., 2022).

A skilled workforce is essential for the successful implementation of innovative waste management systems. Expanding apprenticeship programs and continuous professional development initiatives can bridge skill gaps (Liyanage et al., 2019). Mentorship programs, where experienced professionals guide newcomers, can further reinforce industry best practices (Wong & Gray, 2019).

Successful adoption of waste management innovations requires strategic planning. Companies should develop clear roadmaps with defined objectives, resource allocation plans, and performance metrics (Liyanage et al., 2019). Utilising lean construction principles can enhance operational efficiency and minimise waste production (Han et al., 2021). Engaging all levels of an organisation in the planning phase fosters a culture of innovation and ensures the smooth integration of new technologies (Bamigboye et al., 2019).

Theft and vandalism of high-value waste management equipment pose significant risks. Implementing robust security protocols, including surveillance systems, GPS tracking, and alarm systems, can protect investments (Oke et al., 2023). Comprehensive insurance policies covering technology-related risks can further safeguard assets, ensuring business continuity in case of security breaches (Zainu, 2019).

Collaboration between the public and private sectors can accelerate the adoption of innovative waste management solutions. Government-led initiatives providing funding, technical expertise, and regulatory support can encourage private-sector participation (Kupusamy et al., 2019). Public-private partnerships can help a lot of people use sustainable waste management methods by encouraging everyone in the industry to work together, share information, and pool their resources (Noiki et al., 2021).

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Further research is needed to explore the cost-benefit analysis of innovative waste management technologies, particularly in developing countries (Ma et al., 2022). Establishing a centralised knowledge hub for sharing best practices, case studies, and research findings can facilitate evidence-based decision-making (Ghaffar et al., 2020). Policies that encourage the use of AI and big data in waste management can also make operations run more smoothly (Tian et al., 2018). By addressing these recommendations, the construction industry can transition towards sustainable waste management practices, reducing its environmental impact while improving operational efficiency.

3.0 RESEARCH METHODOLOGY

This study employs a quantitative research methodology, focusing on numerical data to assess the adoption and challenges of innovative waste management systems in the Malaysian construction industry. The rationale for this approach is its ability to provide objective, measurable, and replicable results (Chen et al., 2021). Quantitative methods are particularly useful for identifying patterns, establishing correlations, and enabling generalisations to a broader population (Maraqa et al., 2021).

The research was conducted within the Malaysian construction sector, specifically targeting G7 contractors registered with the CIDB. The Klang Valley region was selected due to its high concentration of construction projects and significant impact on waste management practices (Asnor et al., 2022). This study aims to address the sector's need for sustainable practices and enhanced waste reduction measures.

A probability sampling technique was adopted to ensure a representative selection of respondents. Using stratified random sampling, contractors were classified based on their level of involvement in construction waste management. The target sample size was 155 respondents, calculated as 3% of the total 5,194 registered G7 contractors in Selangor and Kuala Lumpur. However, 73 responses (47%) were collected, which were deemed sufficient for statistical analysis.

The data were analysed using SPSS statistical software (version 27). Descriptive statistics were applied to compute mean, median, standard deviation, and frequency distributions (Maraqa et al., 2021). The technology acceptance model was applied in this study to look at how perceived usefulness and perceived ease of use affect people's plans to use new technologies for managing waste.

4.0 FINDINGS AND DISCUSSIONS

This section presents the findings of the study derived the questionnaires distributed. The findings are divided into three (3) sections: demographic information, impediments to implementing innovative waste management, and recommendations on encouraging innovative waste management.

4.1 Demographic Information

Table 1 details the distribution of the professionals and organisations involved in this study. The demographic analysis of the study shows that most of the respondents (43.8%) were project managers, followed by site supervisors (37%), managing directors (15.1%), and chief executives (4.1%). The working experience distribution shows that 38.4% of respondents had 11 to 15 years of experience. Most respondents were engaged in residential building projects (35.6%), followed by commercial (27.3%), civil engineering (21.2%), and industrial (15.9%). Furthermore, 39.7% of the respondent's involvement projects were valued at over 60 million MYR.

It can be concluded that majority of the respondents held managerial positions and had over 10 years of industry experience. Furthermore, a significant portion of the respondents were involved in housing projects valued at over 50 million MYR. This evidence implies that individuals responsible for making decisions and managing construction waste actively participated in the study. Moreover, they have

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significant industry exposure and expertise in innovative waste management across the diverse construction industry. Their insights and perspectives significantly influenced the results of the study, thereby establishing the reliability of the research.

Table 1. Demographic information

Designation	**Percentage%**	**Type of project involved**	**Percentage%**
Chief Executive Officer	4.1	Commercial	16.4
Managing Director	15.1	Industrial	24.7
Project Manager	43.8	Residential	38.4
Site Supervisor	37.0	Civil Engineering	15.1
Working Experience	**Percentage%**	**Size of Project Implemented Innovative Waste Management (MYR)**	**Percentage%**
Less than 5 years	16.4	Less than 2 million	6.8
6 – 10 years	24.7	3 – 20 million	17.8
11 – 15 years	38.4	21 – 40 million	16.4
16 – 20 years	15.1	41 – 60 million	19.2
More than 21 years	5.5	More than 60 million	39.7

4.2 The Challenges in Implementing Innovative Waste Management

Table 2 indicates the challenges in implementing innovative waste management in the Malaysian construction industry. The study highlights that the lack of knowledge (mean score = 4.58, standard deviation = 0.780) ranks as the most significant challenge to adopting innovative waste management technologies. Workplace safety concerns (mean score = 4.48, standard deviation = 0.988) rank second, emphasising the necessity of proper training to mitigate accident risks.

The lack of knowledge emerges as the most critical challenge to adopting innovative waste management technologies in the Malaysian construction industry. The evidence indicates that many industry professionals lack awareness of sustainable waste management solutions, leading to continued reliance on traditional disposal methods. Zhang et al. (2019) suggest that the implementation of targeted educational programs, including case studies, workshops, and seminars, can bridge this knowledge gap and facilitate knowledge transfer. In addition, collaboration between government agencies, academic institutions, and private stakeholders can enhance industry awareness and provide up-to-date information on technological advancements (Tambovceva et al., 2020). Without adequate knowledge, decision-makers may perceive innovative waste management as complex or unfeasible, further delaying adoption (Turkyilmaz et al., 2019).

Workplace safety concerns rank as the second most significant challenge. This incident highlights the risks associated with handling waste management technologies without proper training. Ishak et al. (2022) emphasise the importance of comprehensive safety programs, including initial training and continuous refresher courses to mitigate accident risks and ensure compliance with evolving industry standards. Companies should integrate safety training into their onboarding programs and establish regular safety audits to address potential hazards. Furthermore, technology developers must focus on designing user-friendly, automated waste management solutions that minimise direct human interactions with hazardous materials (Al-Otaibi et al., 2022).

Addressing these challenges requires a multi-faceted approach involving education, structured safety protocols, and regulatory support. Increasing industry collaborations, putting in place financial incentives, and making government policies stronger can all aid more people in using sustainable waste management strategies. This will eventually lead to less construction waste and better environmental sustainability (Ghaffar et al., 2020).

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Table 2. The challenges in implementing innovative waste management

Description	Mean Score	Standard Deviation	Rank
Lack of knowledge: lack of awareness or understanding among contractors of innovative waste management technologies and strategies.	4.58	0.780	1
Lack of skills: even if individuals are aware of innovative waste management solutions, they may lack the necessary skills or expertise to implement them effectively.	4.34	0.839	6
High initial cost: the initial cost of implementing innovative waste management systems, such as investing in advanced sorting equipment.	4.47	0.818	4
Government support and policies: inadequate government support and unclear or inconsistent policies related to waste management.	4.45	0.556	5
Inadequate incentives: the lack of financial or regulatory incentives in adopting innovative waste management practices.	4.47	0.625	3
Lack of adoption strategies: even if innovative waste management solutions are available, there may lack of effective strategies in promoting their adoption within the construction industry.	4.11	0.614	7
Workplace safety concerns: without proper training, there is a risk of accidents and injuries.	4.48	0.988	2
Vandalism and theft: the operation of compacting mechanisms poses safety risks if not properly managed.	3.62	1.113	8

4.3 Recommendations for Encouraging Innovative Waste Management

Table 3 outlines recommendations for encouraging innovative waste management among industry practitioners. The study highlights that providing incentives (mean score = 4.62, standard deviation = 0.543) ranks as the most effective approach to encouraging the adoption of innovative waste management systems. Studying innovative waste management systems (mean score = 4.60, standard deviation = 0.571) ranks second, underscoring the importance of thorough research and analysis before implementation.

The study highlights that providing incentives ranks as the most effective approach to encouraging the adoption of innovative waste management systems. This finding suggests that financial and regulatory incentives play a critical role in motivating stakeholders to embrace sustainable waste management solutions (Al-Otaibi et al., 2022). Previous studies have shown that incentives such as tax reductions, government subsidies, and grants can accelerate the implementation of innovative technologies in the construction industry (Ghaffar et al., 2020). Additionally, non-monetary incentives, such as industry recognition and certification, can further enhance adoption rates by rewarding companies that implement sustainable practices (Zhang et al., 2019).

Studying innovative waste management systems ranks second, emphasising the importance of research and analysis before implementation. A comprehensive understanding of various waste management technologies ensures that construction firms can select the most effective and cost-efficient solutions tailored to their specific project needs (Tambovceva et al., 2020). Moreover, case study-based learning and pilot projects can serve as practical examples, demonstrating the feasibility and benefits of innovative waste management practices (Zhang et al., 2019). Research-driven decision-making minimises risks associated with adopting new systems and enhances industry confidence in innovative approaches.

To effectively encourage the adoption of waste management innovations, it is essential to combine financial incentives, regulatory support, and knowledge dissemination. Strengthening policies, providing financial assistance, and conducting industry-wide awareness campaigns can facilitate the widespread implementation of sustainable waste management solutions in construction (Ishak et al., 2022). A holistic approach that integrates financial, educational, and regulatory measures will drive long-term sustainability and resource efficiency in the industry.

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Table 3. Recommendations for Encouraging Innovative Waste Management

Description	Mean Score	Standard Deviation	Rank
Studying innovation waste management systems: begin by conducting thorough research and analysis of innovative waste management systems that are suitable for construction projects.	4.60	0.571	2
Practical and efficient plan: develop a practical and efficient plan for integrating innovative waste management systems into construction projects.	4.40	0.595	6
Innovation financial mechanism: explore innovative financial mechanisms to fund the implementation of waste management systems, such as partnerships.	4.58	0.551	3
Government support and policies: engage with policymakers to promote the development of supportive regulations, incentives, and funding programmes.	4.55	0.554	5
Incentives: provide incentives to encourage stakeholders to adopt innovative waste management systems.	4.62	0.543	1
Arranged strategies: develop comprehensive strategies for arranging and implementing innovative waste management systems.	4.03	0.781	7
Workplace safety training: provide comprehensive safety training for workers on how to operate and maintain new waste management equipment which can prevent accidents and injuries.	4.58	0.575	4
Security measures: install protective enclosures and security systems, such as cameras and alarms.	3.90	0.930	8

5.0 CONCLUSIONS

Innovative waste management in construction is essential for sustainability, cost efficiency, and environmental protection. However, challenges such as high costs, lack of knowledge, safety concerns, and weak government support hinder adoption. Addressing these requires action from governments, industry leaders, and policymakers.

Governments should offer tax incentives, grants, and stricter regulations to promote sustainable waste practices. Countries like Sweden and Germany have reduced waste through landfill taxes and recycling policies. Japan's prefabrication methods minimise material waste, providing a model for efficiency. The industry must invest in workforce training and sustainable financing. The Netherlands' circular economy initiatives, funded through green loans, show how businesses can finance sustainable solutions. Collaboration with research institutions can drive technological advancements.

Policymakers should establish long-term strategies and compliance measures. South Korea's waste-to-energy programs demonstrate how technology can optimise waste conversion. AI-driven waste sorting and data analytics can enhance efficiency and reduce environmental impact. Improved waste management lowers costs, creates business opportunities in recycling, and reduces carbon emissions. Sustainable practices protect ecosystems, conserve resources, and support climate action.

This study differs from past research by integrating AI, financing, and global best practices into construction waste management, emphasising data-driven decisions and collaboration to overcome financial challenges and enhance real-world implementation. Future studies should explore AI-driven waste management, circular economy models, and predictive analytics. Research on global best practices can provide scalable solutions for sustainable construction. A coordinated approach integrating policy, education, financing, and technology is key to driving sustainability in the construction industry. By adopting global best practices and leveraging innovation, stakeholders can ensure long-term environmental and economic benefits.

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6.0 CONTRIBUTION OF AUTHORS

The authors contributed equally to the body of the work as well as the article.

7.0 FUNDING

This work did not get any specific funding from any organisation.

8.0 CONFLICT OF INTEREST STATEMENT

The authors agreed that this research was conducted without any personal benefits, commercial interests or financial conflicts and declared no conflicts of interests with the funders.

9.0 ACKNOWLEDGEMENT

Many thanks to Universiti Teknologi MARA (UiTM) Shah Alam, especially the Green Lean Build Synergy (G-LeanB) of the College of Built Environment, UiTM Shah Alam, for offering a platform that fosters academic contributions to the industry.

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