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Green Construction in Malaysia: Integrating Regulation, Sustainability, and Innovation for a Resilient Future

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ABSTRACT: Malaysia's construction industry has experienced steady growth since its independence, with the infrastructure sector projected to reach a market value of approximately USD 41.85 billion. This review article aims to evaluate the industry through the lens of environmental compliance, technological advancement, and sustainable development practices. Despite contributing to a 4.1% increase in Gross Domestic Product (GDP) over the past two decades, the industry continues to exert significant environmental pressure. To address these challenges, strict adherence to environmental regulations and standards is essential. One critical requirement is the development of an Environmental Management Plan (EMP) prior to project commencement. The EMP outlines procedures such as baseline environmental assessments, identification of potential adverse impacts, emergency response planning, stakeholder roles and responsibilities, staff training, and ongoing monitoring and enforcement. In parallel with regulatory compliance, the transition toward green construction practices is gaining momentum. This includes the use of sustainable materials such as recycled concrete and aerogels, and the integration of smart technologies like Building Information Modeling (BIM) and drone-based site monitoring. These innovations not only enhance construction efficiency and safety but also reduce the industry's ecological footprint. This paper explores the dynamic interplay between environmental responsibility, regulatory frameworks, and technological innovation, positioning green construction as a vital pathway for Malaysia's sustainable development.

KEYWORDS: Green construction; environmental compliance; sustainable development; construction industry; technological innovation.

1. Introduction

The construction industry in Malaysia developed rapidly as it straddled the line between economic and ecological sustainability amid rapid urbanisation, aiming to stabilise both dimensions. Since the country's independence, Malaysia's construction sector evolved significantly from manual labour and rudimentary tools in its early stages when technological advancement was limited [1]. According to a study by Kamal et al., the industry became vital to the national economy, creating employment in material supply, consultancy, and design development, while contributing to infrastructure growth through the construction of roads, buildings, bridges, tunnels, and similar projects [2].

In 2023, Malaysia's construction sector continued to expand, recording a total project value of MYR 54.71 billion between January and October. The industry was projected to reach a market value of USD 41.85 billion by 2025, with expectations to rise to USD 63.07 billion by 2030—equating to a compound annual growth rate of 8.55% from 2025 to 2030 [3]. A comparison of GDP contributions over a decade revealed that the industry contributed RM13.7 billion in Q1 2015, increasing to RM17.4 billion in Q4 2024, representing 4.1% of Malaysia's total GDP [4]. Despite this rapid development, Malaysia's construction sector continued to face persistent challenges, including poor quality and productivity, project delays, inadequate maintenance, poor working conditions, insufficient worker training, and lack of on-site safety awareness [1]. Moreover, several projects failed to comply with key regulations, such as the Occupational Safety and Health Act (OSHA) 514. According to the Department of Statistics Malaysia (DOSM), occupational injury cases rose by 13.8% between 2022 and 2023, with the injury risk rate increasing from 2.26 to 2.46 [5].

As the sector progressed, environmental responsibility emerged as a pressing concern. Poor practices including inadequate material and waste management, excessive emissions, non-compliance with environmental assessments, and insufficient safety supervision, posed serious environmental threats [6]. Malaysia generated approximately 25,600 tonnes of construction and demolition waste daily, comprising materials such as glass, plastic, wood, steel, and broken bricks [7]. On a global scale, the construction industry was responsible for 25% of greenhouse gas emissions, 40% of energy use, and over 50% of landfill waste, factors that contributed to frequent climate-related disasters in Malaysia [8]. To promote greener practices, Malaysia introduced the Green Building Index (GBI), which evaluates building projects based on their use of sustainable materials and energy efficiency. International green certifications like Leadership in Energy and Environmental Design (LEED) and Green Real Estate (GreenRE) by the U.S. Green Building Council (USGBC) also became essential for environmentally responsible construction [9].

In response to escalating environmental concerns, the implementation of Environmental Management Plans (EMPs) became a critical requirement for construction projects [6,10]. Malaysia's construction industry adopted sustainability goals focused on reducing environmental degradation through comprehensive EMPs. These plans emphasised resource efficiency, waste minimisation, and environmental responsibility on job sites. Key objectives included protecting endangered species, reducing environmental risks, ensuring worker safety, and addressing all forms of pollution and land degradation through strategic management of resources and waste [11]. With the effective execution of EMPs, the construction sector in Malaysia could progressively align economic growth with environmental preservation. Table 1 presents an overview of the economic, environmental, and sustainability dimensions shaping

Malaysia's construction industry. This review article aims to critically examine the growth of Malaysia's construction industry with a focus on its environmental challenges, regulatory compliance, and sustainable development strategies.

Table 1. Economic, environmental, and sustainability aspects of Malaysia's construction industry.

Aspect	Key Points	References
Economic Development	-Major contributor to Malaysia's economy. -Drives economic growth and employment opportunities. -Responsible for infrastructure development such as roads, buildings, bridges, and tunnels.	[1, 2]
Growth Trends	- Malaysia's construction sector is projected to reach a value of USD 41.85 billion by 2025. - GDP growth averaged 4.1% over the last decade.	[3, 4]
Legal Compliance Issues	- Compliance with laws and regulations remains inadequate. - Issues include quality deterioration, insufficient worker training, and low safety awareness. - Occupational injuries rose by 13.8% from 2022 to 2023.	[1, 5]
Environmental Challenges	- Problems stem from waste generation, emissions, and lack of environmental impact assessments. - Causes resource depletion, environmental disturbances, and threatens wildlife.	[6, 11]
Environmental Pollution and Waste	- Construction activities produce approximately 25,600 tonnes of waste daily in Malaysia. - Globally, the construction sector contributes 25% of greenhouse gases, 40% of energy use, and over 50% of landfill waste, causing frequent environmental hazards locally.	[7, 8]
Sustainability Plan	- Implementation of comprehensive Environmental Management Plans (EMPs) for ongoing projects is necessary. - Adoption of the Green Building Index (GBI) to evaluate green materials and energy efficiency. - Additional certifications include LEED and GreenRE.	[9, 10]
Sustainability Goals	- EMPs focus on reducing resource consumption and minimizing waste output. - Aim to protect endangered species and preserve the environment. - Ensure worker safety on construction sites.	[10, 11]

2. Government Approvals and Environmental Regulations in Malaysia

Malaysian government agencies such as the Department of Environment (DOE), Natural Resources and Environment Board Sarawak (NREB), Department of Irrigation and Drainage (DID), and the Department of Occupational Safety and Health (DOSH) enforced various laws and regulations to ensure all construction-related projects complied with environmental standards [12]. The legal and regulatory requirements for construction projects are summarised in Table 2. The implementation of these environmental rules created a balance between environmental protection and sustainable economic development, ensuring construction activities operated responsibly. The Environmental Quality Act (EQA) 1974, the cornerstone of Malaysia's environmental regulations, established standards for managing environmental and pollution impacts. Under Section 34A of the EQA 1974, all construction projects, whether small or large-scale, were required to conduct an Environmental Impact Assessment (EIA) by a certified environmental consultant prior to project commencement. The EIA identified potential environmental impacts related to air, water, land, or noise, and proposed mitigation measures to control or reduce these effects. Conducting an EIA before construction was vital, especially in areas where flora and fauna might be affected. Based on the findings, the Director

General had the authority to halt any project deemed harmful to the environment and living organisms [13].

Table 2. Environmental legislation required for construction projects.

Legislation	Management Focus	Detailed Description	References
Environmental Quality (Licensing) Regulations 1977	Licensing	Provides permits for activities that have the potential to impact the environment, ensuring that such operations comply with environmental standards and controls.	[15]
Environmental Quality (Clean Air) Regulations 2014	Air Pollution	Imposes stringent limits on the amount and type of pollutants released into the atmosphere by various sources, aiming to reduce air contamination and protect public health.	[16]
National Water Quality Standards and Water Quality Index	Water Quality	Sets comprehensive benchmarks for the chemical, physical, and biological quality of water bodies, helping to monitor and maintain water safety and ecosystem health.	[17]
Factories and Machinery (Noise Exposure) Regulations 1989	Noise Pollution	Regulates permissible noise levels within industrial and workplace environments to minimize hearing loss and stress among workers and nearby communities.	[18]
Environmental Quality (Control of Emissions from Diesel Engines) Regulations 1996	Diesel Vehicle and Machinery Emissions	Controls and limits the pollutants emitted by diesel-powered vehicles and machinery, targeting reductions in harmful air contaminants from these sources.	[19]
Environmental Quality (Control of Emissions from Petrol Engines) Regulations 1996	Petrol Engine Emissions	Establishes emission standards specifically for petrol-powered engines to curb air pollution, contributing to cleaner air quality.	[20]
Environmental Quality (Scheduled Waste) Regulations 2005	Scheduled Waste Management	Oversees the handling, transportation, and disposal of hazardous wastes to prevent environmental contamination and health hazards.	[21]
Environmental Quality (Sewage) Regulations 2009	Sewage Treatment and Discharge	Provides guidelines for the treatment of sewage and the standards for its discharge into the environment to avoid water pollution and health risks.	[22]
National Construction Policy 2030	Construction Industry Practices	Promotes sustainable construction practices nationwide, integrating environmental protection with development goals to ensure long-term sector sustainability.	[23]
Building Ordinance 1994 (Sarawak)	Building Development Regulation	Regulates building planning, approval, and construction processes in Sarawak, including environmental safeguards and safety measures.	[24]
Local Government Act 1976 (Peninsular Malaysia)	Local Authority Administration	Empowers local governments to oversee project approvals and waste management, ensuring compliance with environmental and safety standards.	[25]
National Land Code 1965 & Town and Country Planning Act 1976 (Peninsular Malaysia)	Land Use and Planning	Governs land administration and urban planning to ensure orderly development, incorporating environmental considerations into land use decisions.	[26, 27]
Occupational Safety and Health Act 1994	Worker Safety	Mandates that all workers receive proper safety training and that these safety practices are rigorously applied on-site to reduce accidents and occupational injuries.	[28]

Additionally, companies were encouraged to obtain ISO 14001 certification to improve the efficiency of their environmental management systems and enhance overall economic performance. This certification process typically included setting environmental goals and measurable targets, preparing for emergencies, incorporating stakeholder input, and making environmental policies publicly accessible. Recognition through ISO 14001 often led to improved operational efficiency, better risk management, reduced construction costs, and stronger community relations [14]. Other key regulations under the EQA 1974 covered areas such as waste management (Sections 21 and 34B), water quality (Sections 25, 27, and 29), soil quality (Section 24), air quality (Sections 21 and 22), and noise pollution (Section 23) [14].

Despite generating up to 25,600 tonnes of construction waste daily in Malaysia, the Construction Industry Development Board (CIDB) has established comprehensive guidelines for proper waste management at construction sites [7, 26]. These guidelines promote the globally recognised Solid Waste Management (SWM) Hierarchy, which emphasises waste minimisation through a systematic approach: reduction, reuse, recycling, waste treatment, and finally, disposal. The hierarchy places the highest priority on waste prevention and the 3Rs, 'Reduce,' 'Reuse,' and 'Recycle' as shown in Table 3. Lower-priority methods, such as recovery treatment and landfill disposal, are to be avoided unless they are the only viable options, typically for hazardous or mixed wastes [29].

Table 3. Description of each aspect of solid waste management hierarchy.

Aspect	Description	Application
Reduce	Focuses on limiting the generation of waste by optimizing resource use and streamlining processes.	Implement sustainable design principles that avoid the need for excess raw materials, prioritize efficiency in construction practices, and select low-waste methods.
Reuse	Involves repurposing materials that would otherwise be discarded, giving them a second life in other applications.	Encourage on-site recovery and repurposing of components like scaffolding, wood panels, and structural steel in new or ongoing projects.
Recycle	Transforms discarded materials into usable products, reducing dependence on virgin raw materials.	Integrate structured recycling initiatives into construction sites, such as sorting and processing concrete, metal, and plastic for re-manufacture or resale.
Waste Treatment	Refers to the process of handling waste materials to reduce their environmental risks before final disposal.	Adopt techniques like chemical neutralization, composting of biodegradable matter, and thermal treatments to ensure wastes are less harmful before being discarded.
Disposal	Acts as the final solution for waste that cannot be reduced, reused, recycled, or treated safely.	Based on the toxicity and nature of the waste, select the most environmentally sound method—typically landfilling, incineration, or composting for organics.

Following the environmental laws and regulations of Malaysia is very critical, and preparing documents for construction plans also plays an important role in the industry, as the approval process from the authorities is done by primarily looking based on environmental and sustainability aspects of the project planning where Malaysia's laws set their standards [30, 31]. However, delays in project plan approval process do happen in Malaysia's construction industry, where a survey study found that a building plan approval process in Subang Jaya Municipal Council (MPSJ) had caused delays due to a lack of knowledge and capability among staff responsible for submitting documents to the board of directors, and incomplete document submissions from contractors. Therefore, this study enables people involved in a building project to understand how an effective building plan process enables the successful justifying of the property development sector [32].

3. Environmental Management Plans (EMPs)

3.1. Overview.

An Environmental Management Plan (EMP) referred to a structured program designed to achieve ideal environmental outcomes by identifying how construction activities could adversely affect the environment and living organisms. The plan specified mitigation measures, regulatory actions, and ongoing monitoring throughout project phases, including commissioning, mobilisation, construction, operation, maintenance, and decommissioning, all aimed at enhancing the project's positive impacts. As Malaysia experienced rapid urban settlement and industrial expansion with potential environmental repercussions, developing an EMP became particularly significant. The primary objective of a comprehensive EMP was to ensure construction projects complied with environmental laws and regulations while promoting eco-friendly development through systematic natural resource management [6,13]. Beyond regulatory compliance, EMPs fostered public trust and enhanced the reputations of construction firms [6, 12]. The plan included strategies for waste management, pollution prevention, and conservation of natural resources throughout the project lifecycle—from development and implementation to assessment and monitoring [6]. Given the critical importance of EMPs, they promoted ecological balance and ensured that construction projects contributed positively to the environment rather than causing harm [6, 12, 32].

However, achieving the objectives of EMPs proved challenging in developing countries like Malaysia, largely due to insufficient financial support and a lack of stringent enforcement of comprehensive EMP requirements. This resulted in difficulties promoting sustainability effectively. Studies found that awareness and commitment to EMP implementation among Malaysian project stakeholders remained limited, as the process demanded extensive professional consultation and implementation efforts, imposing financial burdens on contractors and stakeholders. Consequently, insufficient environmental knowledge and consideration led to EMPs being neglected or implemented superficially [6]. Similarly, efforts to adopt green construction practices and integrate EMPs into building planning faced comparable struggles. Although sustainable construction methods had been demonstrated in Malaysia over the past decade to reduce environmental risks, uptake remained slow. The industry's sluggish acceptance of green construction was attributed to limited engagement from stakeholders and material suppliers, a shortage of environmental policy expertise, lack of skilled personnel, and high costs associated with meeting green engineering standards [6, 33]. For sustainable environmental protection amidst rapid urbanisation, it remained crucial that stakeholders, project designers, and contractors adhered to Malaysia's environmental legislation by implementing comprehensive EMPs in a sustainable and economically feasible manner.

3.2. Components of an effective EMP.

3.2.1. Site assessment and baseline data.

Conducting site assessments and collecting baseline data were crucial components in planning a comprehensive EMP. Site assessments typically involved examining the physical, biological, and socioeconomic parameters of the location, including identifying native living organisms, evaluating soil and water quality, analysing existing infrastructure, and recording potential environmental impacts [34]. To ensure effective baseline data collection, an Environmental Impact Assessment (EIA) was necessary for compliance with Malaysia's laws and international regulatory standards [12].

Furthermore, incorporating local ecological knowledge and engaging with the community during project implementation benefited both the environment and the local population. This was especially important in Malaysia due to its rich biodiversity and diverse ecosystems, often achieved through a Social Impact Assessment (SIA). For example, involving Indigenous communities provided accurate assessments of local biodiversity and historical land use patterns [34]. To align with modern technological advances, tools such as remote sensing and Geographic Information Systems (GIS) enhanced the mapping and analysis of environmental characteristics and impacts [35]. Research on oil palm plantations in Borneo highlighted significant variations in wet inorganic nitrogen deposition, demonstrating the importance of context-specific data for informed management decisions [36]. Ultimately, the baseline data collected on-site supported sustainable development by guiding mitigation strategies, ensuring regular compliance with environmental policies, and serving as a reference for predicting future environmental impacts [12].

3.2.2. Identification of potential environmental impacts.

After conducting site assessments and collecting baseline data, identifying environmental impacts from pre- and post-construction activities was crucial to preventing adverse effects on the environment while protecting native cultures and local ecosystems. To ensure all potential impacts were addressed, consultations with environmental professionals and project stakeholders were made mandatory, allowing project developers to verify that every aspect of the work complied with Malaysia's legislation [6, 13]. If potential environmental impacts were not identified, most legislation listed in Table 4 would have been violated. Scheduled wastes could have been discharged into inland waters and native soils, causing pollution and potentially eliminating flora and fauna. Emissions from vehicles and machinery could have increased greenhouse gas levels in the atmosphere. Noise generated during construction could have disrupted local communities and diverse habitats. Additionally, construction waste could have contributed to landfill overflow if the Solid Waste Management (SWM) hierarchy was not properly applied [7–8, 16–21]. Ultimately, evaluating potential environmental impacts enabled project developers to design effective mitigation measures, ensuring the long-term sustainability of construction projects.

3.2.3. Mitigation measures.

When potential environmental impacts are identified during the analysis of work activities of a construction project, mitigation measures are required as mentioned in EQA 1974. The effective development of an EMP is usually reached when implications are evaluated, followed by a completed EIA with appropriate background studies for the construction project and work site. The relevance of mitigation measures recommended during the impact evaluation is shown in EIA or SIA. When an EMP is created, the projected residual impact of executing the recommended mitigation strategies is crucial. Thus, the EMP describes the mitigation strategies for prevention, reduction, and remediation of any impacts caused to the environment [11].

Table 4. Mitigation measures of a construction project for EMP.

Pollution Type	Source	Mitigation Measures	Applicable Regulations/Standards
Air Pollution	Onsite (construction machinery and vehicles)	- Suppress dust using water spraying. - Cover transported materials. - Operate fuel-efficient machinery. - Conduct regular equipment maintenance. - Avoid work during strong winds.	- Environmental Quality (Clean Air) Regulations 2014 - Environmental Quality (Control of Emissions from Diesel Engines) Regulations 1996 - Environmental Quality (Control of Emissions from Petrol Engines) Regulations 1996
	Offsite (transport vehicles)	- Ensure proper vehicle maintenance. - Train drivers in fuel-efficient and anti-idling practices. - Avoid using outdated vehicles.	Same as above
Water Pollution	Wastewater from worker camps and equipment cleaning	- Install temporary sewage systems. - Avoid siting camps near water bodies. - Treat greywater using artificial treatment ponds.	- National Water Quality Standards and Water Quality Index - Environmental Quality (Sewage) Regulations 2009
Land Pollution	Solid waste from excavation, construction, demolition, and worker activities	- Dispose of waste only at designated facilities. - Implement a 3R (Reduce, Reuse, Recycle) strategy. - Minimize reliance on landfill collection.	- Environmental Quality (Scheduled Waste) Regulations 2005
Noise Pollution	Heavy machinery and vehicle operations	- Avoid noisy operations during peak and nighttime hours. - Ensure machinery is well-maintained. - Prioritize low-noise equipment.	- Factories and Machinery (Noise Exposure) Regulations 1989 - National Construction Policy 2030
Others	Soil erosion and sedimentation from excavation and runoff	- Install sediment traps and silt fences. - Use erosion control mats or blankets. - Reuse excavated spoil as refill material where appropriate.	- Best Engineering Practices

3.2.4. Monitoring and reporting.

During visits to ongoing construction projects, construction monitoring had to be conducted, and reports were required to ensure that mitigation measures were properly implemented. Any necessary changes were to be analysed and approved by general directors. This process ensured that the principles of green construction were maintained. While mitigating and reducing environmental impacts, environmental monitoring enabled infrastructure projects to regularly comply with environmental permits and regulations. In the construction industry, the most common monitoring activities involved water quality and ambient air, where environmental consultants followed the National Water Quality Standards, Water Quality Index, and Environmental Quality (Clean Air) Regulations 2014. Other recommended monitoring activities included noise levels and land quality. On-site testing of construction materials and completed works was also considered part of monitoring, allowing project developers and contractors to make improvements and recommendations. Finally, environmental consultants prepared reports after consultations with project developers [33].

3.2.5. Emergency response plan (ERP)

The Occupational Health and Safety Act (OSHA) 1994 required every infrastructure project to establish emergency response procedures. Being prepared for emergencies helped reduce the duration of injuries and economic losses. Emergency response planning had to be completed before work commenced on construction projects [28]. Developing an ERP involved identifying and assessing hazardous substances, allocating emergency resources, establishing communication systems, appointing a person responsible for the plan, defining response procedures, communication protocols, and post-emergency procedures including debriefing and addressing post-traumatic stress [37].

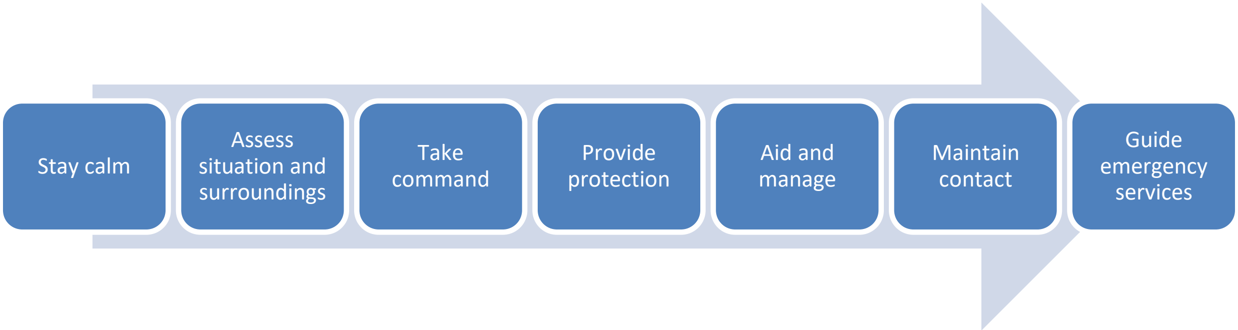

Figure 2. Emergency response procedure.

3.2.6. Responsible roles; training and awareness.

Individual roles and responsibilities in infrastructure projects were specified in an EMP to ensure its effective implementation. An assigned environmental officer supervised every aspect of the EMP, managing mitigation initiatives and ensuring regulatory compliance [38]. Additionally, this individual served as the main contact for environmental concerns, overseeing operations both onsite and offsite and facilitating communication. All construction personnel participated in comprehensive training and awareness programs that addressed the objectives of the EMP, specific mitigation measures, and their responsibilities in environmental protection [39]. These programs included hazardous spill response, waste management, noise control, and erosion prevention, enabling personnel to understand how their roles contributed to reducing the project's environmental footprint. To foster a sense of responsibility and maintain environmental consciousness on-site, safety seminars, site inductions, and regular training sessions were considered essential [40–41].

3.3. Implementation and enforcement.

For an EMP to be effectively implemented, it must be fully integrated into the overall project management system rather than treated as a separate document [42]. The EMP should be embedded within the processes of project planning, monitoring, and execution. To ensure that all environmental aspects of the infrastructure project are addressed properly, consistent communication and coordination among stakeholders, project developers, environmental officers, and consultants are essential. This can be achieved through regular weekly meetings and progress updates delivered via physical or digital platforms [43].

Additionally, stringent enforcement measures are necessary to guarantee adherence to the EMP and applicable environmental regulations [44]. Regulatory bodies such as the

Department of Environment (DOE) play a crucial role in site inspections, monitoring, and enforcing penalties for non-compliance. These penalties serve both as punishment and deterrence and may include fines, project suspensions, or site shutdowns. Routine EMP audits conducted by both internal and external parties help assess the plan's effectiveness and identify areas for improvement [45]. Ultimately, these audits promote a culture of environmental responsibility and continuous enhancement throughout the project's duration by verifying that mitigation measures are properly applied, data monitoring is accurate, and any deviations from the EMP are promptly corrected.

4. Moving Towards Green Construction

As the global construction industry advances, the urgency to adopt sustainable practices has intensified. A vital strategy to lessen environmental impacts while enhancing building sustainability involves incorporating green building materials alongside innovative smart technologies [46]. These advancements include tools such as Building Information Modeling (BIM), smart sensors, and the Internet of Things (IoT), while eco-friendly materials like bamboo, cork, recycled components, and aerogels are increasingly used. By leveraging these developments, infrastructure developers can design projects that support environmental preservation and improve occupant wellbeing, paving the way for healthier, more sustainable environments [47].

4.1. Recycled concrete.

With Malaysia's construction sector expanding, the demand for building materials and the generation of construction waste—especially concrete waste—has surged. Concrete debris is commonly found at demolition sites, production facilities, and in leftover ready-mix loads [48]. Research estimates that concrete aggregate waste accounts for about 65.8% of Malaysia's construction waste. If not properly managed, this waste can lead to environmental problems like dust pollution and water contamination [48]. Recycling concrete presents a promising solution to reduce cement production costs and mitigate environmental damage from manufacturing. Studies have shown that combining recycled concrete with coarse aggregate, sand, and water, followed by moulding and curing, can produce new concrete blocks. These blocks have thermal properties that help moderate indoor temperatures, reducing the need for air conditioning [49]. This technique offers a sustainable option for future residential construction in Malaysia.

4.2. Aerogels.

Aerogels, renowned for their exceptional thermal insulation, represent a potential breakthrough for the construction industry [50]. Made primarily of silica, these thin, transparent materials provide far superior insulation compared to conventional options, thereby reducing energy consumption for heating and cooling [51]. In tropical climates such as Malaysia, aerogel insulation can significantly decrease heat transfer into buildings, cutting air-conditioning costs and lowering carbon emissions [52]. Despite their high initial cost, the long-term energy savings and environmental benefits make aerogels an attractive choice for sustainable construction [53].

4.3. Smart technologies.

Smart technologies are revolutionizing infrastructure development by enhancing efficiency and sustainability. Building Information Modeling (BIM) creates detailed digital models of projects, reducing waste and errors through precise planning, conflict detection, and optimized material use [54]. Meanwhile, drones equipped with LiDAR sensors and high-resolution cameras enable real-time site monitoring, progress tracking, and safety inspections, improving oversight and minimizing risks [55]. These technologies also facilitate better communication and collaboration among stakeholders, streamlining project workflows and outcomes. By adopting BIM and drone technology, Malaysia's construction sector can boost productivity, foster innovation, and significantly reduce its environmental footprint.

5. Conclusion

The construction industry worldwide is progressively integrating green and sustainable engineering principles. In Malaysia, while infrastructure project approvals continue, the government must enforce stricter measures against projects that neglect environmental regulations, imposing significant penalties where necessary. Mandatory implementation of EMPs is essential to ensure all projects adopt sustainable practices that minimize harm to air, water, land, and noise environments. Although Malaysia is gradually embracing green materials like bamboo and insulation technologies, managing construction waste remains a critical priority to reduce landfill burdens. Incorporating modern technologies such as drones can help control project costs while enhancing sustainability. Ultimately, fostering environmental awareness through continuous training and education for all personnel involved is vital to safeguard public health and protect the environment throughout Malaysia's construction industry.

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Author Contributions

Ahmad Faizal Mohd Yusof contributed to the conceptualization, project administration, and manuscript supervision. Cut Yusnar was responsible for data curation and initial draft preparation. Yuangga Rizky Illahi conducted the literature review, prepared visualizations, and performed formal analysis. Rabin Maharjan contributed to methodology development and validation. Hasti Widyasamratri contributed to writing review and editing, and contextual framework analysis.All authors have read and approved the final version of the manuscript.

Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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