Civil and Sustainable Urban Engineering

Review
Volume 5(1), 2025, 69–87
https://doi.org/10.53623/csue.v5i1.689

Challenges and Opportunities in Implementing Green Building Materials in Malaysia

Aimie Peace Siganul[1], Surya Dewi Puspitasari[2]*

[1]Department of Civil and Construction Engineering, Curtin University, CDT 250, Miri 980009, Malaysia
[2]Department of Civil and Environmental Engineering, the Norwegian University of Science and Technology, Trondheim, Norway

*Correspondence: puspitasariaya@gmail.com

SUBMITTED: 16 May 2025; REVISED: 16 June 2025; ACCEPTED: 20 June 2025

ABSTRACT: Sustainable construction is essential for minimizing greenhouse gas emissions, reducing waste, and promoting cost efficiency. However, Malaysia faces persistent challenges in environmental management, development approval procedures, and the adoption of green technologies. While various studies have explored individual aspects of sustainability in construction, there remains a lack of comprehensive reviews that critically assess how regulatory frameworks, approval processes, and green technologies intersect to influence sustainable construction outcomes in the Malaysian context. This review addresses that gap by synthesizing current practices, identifying key bottlenecks, and proposing actionable strategies for improvement. It evaluates regulatory frameworks, environmental strategies, green materials, and advanced technologies that support sustainable construction. The efficiency of the development approval process including project proposals, land acquisition, planning approval, occupancy, and handover plays a crucial role in enabling sustainable outcomes. Green technologies such as renewable energy, solar power, and smart construction techniques like the Internet of Things (IoT) are examined for their potential to enhance sustainability. The review also highlights persistent gaps in cost management and regulatory enforcement. By consolidating diverse strands of knowledge, this paper contributes to a clearer understanding of systemic barriers and opportunities within Malaysia’s sustainable construction landscape, offering policy and practice recommendations to guide future progress.

Keywords: Sustainable construction; Malaysia; green technologies; development approval procedures

1. Introduction

Sustainable construction aims to restore the balance between natural and built ecosystems and to create communities that uphold human dignity [1]. The 17 Sustainable Development Goals (SDGs) under "Agenda 2030"—focused on people, planet, and prosperity—were adopted by all 193 United Nations member states. In 2015, the Paris Agreement legally bound countries to limit global warming to below 1.5°C above pre-industrial levels. In 2019, warnings indicated that only 11 years remained to prevent irreversible damage from climate change. As a result, efforts to address current problems had to be swift, and global consensus was needed that climate change posed a serious threat. In response, sustainable practices in the construction sector have gained attention, especially through the use of green building materials that are resource-efficient, environmentally responsible, and have minimal impact throughout their life cycle, from production to disposal. These materials play a key role in reducing emissions, conserving energy, and improving the overall environmental performance of buildings [2].

Malaysia, as a signatory to both the SDGs and the Paris Agreement, has committed to transitioning towards low-carbon development. The country's Twelfth Malaysia Plan (2021–2025) outlines strategies to integrate sustainability into economic growth, including promoting green infrastructure, improving energy efficiency, and increasing renewable energy adoption. Malaysia's construction sector plays a significant role in national development but also contributes heavily to environmental degradation. The sector consumes substantial energy and resources, generates high levels of waste, and is responsible for approximately 25% of the nation's greenhouse gas emissions. According to the Construction Industry Transformation Programme (CITP) 2016–2020, the industry must adopt sustainable practices, including the use of green materials, advanced technologies, and streamlined regulatory processes, to reduce its environmental footprint. These national commitments underscore the urgency for sustainable construction practices. Yet, Malaysia still faces practical challenges in enforcement, coordination among agencies, and stakeholder engagement. This review seeks to explore these gaps by examining how environmental management, policy implementation, development approvals, and technological innovation are currently shaping sustainable construction in the country [3, 4].

The construction industry employed several sustainable practices, such as the use of recyclable or renewable materials and the reduction of resource consumption. Creating a healthy and sustainable environment, and establishing building standards, guidelines, and regulations, were examples of sustainable construction methods. Furthermore, important practices included maximizing resource reuse and promoting sustainability through education and training. However, the industry faced numerous challenges. These included the lack of suitable materials, limited building codes and regulations, the scarcity of green and renewable materials, and constrained technological resources. Therefore, new strategies and procedures needed to be developed to overcome these obstacles and improve the effectiveness of current sustainable practices [5].

Sustainable development reduced the environmental impact and the demand for resources during construction. Today, the buildings people use daily remain a major source of greenhouse gas emissions. Sustainable development thus heavily relied on the built environment. Construction consumed 50% of naturally occurring resources, while buildings accounted for 45% of global energy use and nearly 80% of water consumption. Green buildings, by contrast, could reduce energy and water use by up to 40%. Sustainable construction aimed to enhance building performance and life cycle efficiency [2]. To mitigate the negative consequences of construction activities, it became imperative for the sector to prioritize sustainability [3]. This review article seeks to examine the current state of sustainable construction in Malaysia, identify major challenges, and suggest potential solutions. It explores relevant regulatory policies, environmental approaches, eco-friendly materials, and innovative technologies that contribute to sustainable building practices.

2. Current Status of Sustainable Construction in Malaysia

A nation's economic growth was significantly influenced by the construction industry, which created numerous job opportunities. The sector contributed between 3% and 5% to Malaysia's GDP over the past two decades. With the projected population increase to around 41.5 million by 2040, more resources would be required for development [6]. Globally, the building sector consumed 40% of total energy and contributed 25% of greenhouse gas emissions. In Malaysia, the industry's high emission of harmful gases had adverse effects on residents' health, including respiratory illnesses and other diseases. Furthermore, over 50% of landfill waste originated from the construction sector, representing a significant environmental burden.

A study on the operation of six government office buildings in Malaysia showed that these structures used 65% of their energy during occupancy. Currently, Malaysia ranked 30th among countries with the highest emissions [7]. Consequently, natural disasters such as landslides and floods had become more frequent. Acknowledging these environmental threats, Malaysia highlighted the importance of green technologies in construction and aimed to achieve sustainable growth by 2030. In response, the government launched the 12th Malaysia Plan (2021–2025) to promote economic growth and national well-being while preserving environmental sustainability. It also pledged to reduce greenhouse gas (GHG) emissions by 45% by 2030.

To support this national goal, a comprehensive assessment of Malaysia's sustainable construction status and growth potential was essential. Several studies addressed this issue. For example, [8] highlighted the construction sector's environmental challenges amidst ongoing economic growth, while [9] focused on barriers to green building adoption. However, a more integrated understanding of practical strategies at the project level is still lacking.

3. Effective Environmental Management Strategies in Construction Projects

This next section explores effective environmental management strategies that can be applied directly within construction projects to enhance sustainability and reduce environmental impacts (Figure 1).

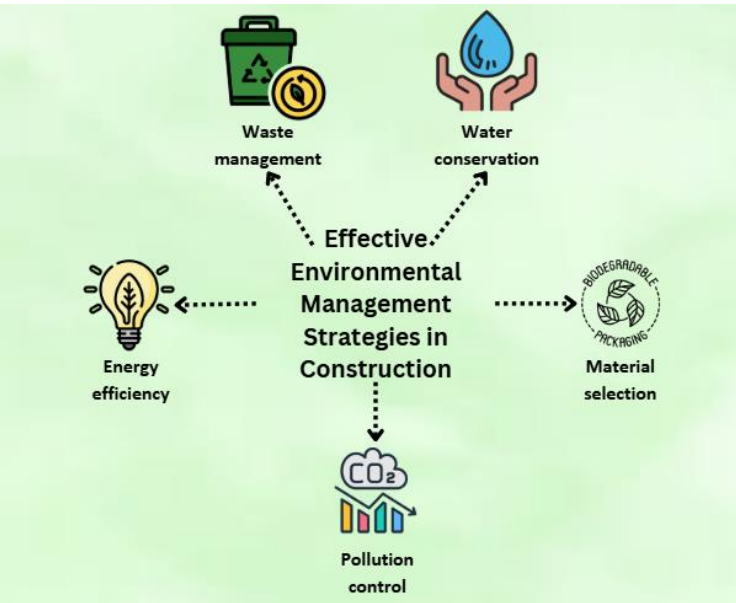

Figure 1. Effective environmental management strategies in construction projects.

3.1. Waste Management.

Waste management was a significant challenge for both present and future generations, indicating a bleak future for those forced to live in polluted environments. Over 23,000 metric tons of trash were produced daily in Malaysia. Furthermore, the amount of metallic waste generated by construction projects worldwide was estimated at 1.3 billion tons and was expected to rise to 27 billion tons by 2050. In addition, material waste reduction was considered a technique that improved project delivery and quality processes, lowered construction costs, and ensured compliance with standards, with clear applications in the modern construction sector [10–12]. Reused building materials came from various phases of construction and demolition, and could easily be applied in new projects. However, the recycling strategy for construction waste involved breaking down building components, which were then combined with other resources to produce new construction materials. This method effectively reduced the amount of waste generated during construction and conserved essential resources. Both recycling and reusing building debris helped lower the carbon emissions associated with construction activities and provided economic and environmental benefits. Since the 3R method (Reduce, Reuse, Recycle) was viewed as a promising approach to extend landfill life and reduce the demand for extensive natural resource extraction, measures needed to be taken to minimize material waste in order to protect the environment [13]. Table 1 summarizes waste management techniques, including their implementation challenges and associated benefits.

Table 1. Waste management techniques for their challenges and benefits.

Waste Management Techniques	Challenges	Benefits	References
3R (Reduce, Reuse and Recycle)	– Requires systemic behavior change. – Quality assurance and storage issues – Contamination, cost, and market fluctuation	– Lowers resource use and cost – Extends material lifespan – Recovers materials, saves energy	[58]
Converting Waste to Energy	– Risk of air pollution and dioxin release – High capital cost, operational expense – Community opposition (NIMBY), awareness gaps – Complex processes, feedstock inconsistency – Regulatory gaps, misaligned incentives	– Reduces landfill waste and methane emissions – Energy generation, job creation, resource recovery – Energy from waste streams, byproduct reuse – Supports circular economy and energy security	[59]
Green Building Practices	– Material sourcing and lifecycle complexities – Higher initial investment – Requires design precision and proper operation – Complex planning and interdisciplinary coordination required – Fragmented policies, lack of incentives – Awareness and behavioral adaptation of users	– Lower emissions, reduced resource use – Lower utility and maintenance costs, increased value – Better air quality, occupant wellness – Advanced systems improve performance – Easier compliance, CSR enhancement – Community support, improved living conditions	[60]

3.2. Greywater Treatment in Construction

Malaysia saw rapid progress in several areas, such as industry, urbanization, and tourism, in its effort to become a developed nation by 2050. The quantity of wastewater released into water channels from both domestic and industrial sources increased as a result of continuous development, leading to water pollution. Domestic wastewater included several types: black, brown, yellow, grey, and white water. According to research [14], greywater constituted between 50% and 70% of all household and construction wastewater and originated from showers, kitchens, toilet flushing, and site cleaning. Greywater was considered the primary alternative water source due to its comparatively low organic pollutant concentration (around 30%) and low nutrient levels (ranging from 9% to 20%). Compared to other sources, greywater was relatively abundant and easier to treat.

Greywater discharges were highest during the hours before and after standard working times. However, it was strongly recommended to treat greywater before reuse to avoid environmental or biological harm. Treatment included several stages such as chemical, physical, biological, and disinfection. Typically, treatment began with screening to remove suspended solids, followed by sedimentation. Pre-treated greywater was then processed through primary treatment systems, which involved biological (membrane bioreactor, MBR), physical (filtration and sedimentation), and chemical (coagulation and activated carbon) methods. This process enabled the reuse of greywater from construction to conserve water. However, in Malaysia, the implementation of greywater reuse was uncommon due to limited resources and insufficient knowledge to support greywater systems. Greywater was typically treated together with blackwater in centralized treatment facilities, unlike in some other countries [15].

3.3. Material selection.

Waste generation increased with global population growth. Urbanization significantly contributed to the growing solid waste crisis, particularly in developing countries that lacked conventional waste management systems and faced economic challenges. The absence of regulations often led to informal waste processing and inappropriate disposal methods, such as open dumping, posing serious environmental risks. Malaysia’s rapid development generated over 25,600 tons of construction and demolition debris daily. According to research [16], traditional pavement materials such as concrete, asphalt, and natural aggregates, were used up until 2005. Afterward, several researchers began exploring alternative materials for pavement construction. This included a life cycle assessment (LCA) of various waste materials such as reclaimed asphalt pavement (RAP), recycled concrete aggregate (RCA), waste plastics, and more.

Material selection focused on enhancing pavement performance while reducing environmental impact. For example, RCA, produced from demolished concrete structures, could be reused in new construction to reduce material waste and resource consumption. According to research [17], asphalt mixes modified with waste polypropylene and polyethylene showed better adhesion and durability, with improved resistance to rutting and reduced moisture damage caused by aging. Thus, reused materials offered durability, efficiency, and sustainability comparable to, or better than, new materials [18, 19].

3.4. Pollution control.

According to the Department of Environment, the minister highlighted the issue of “air impurities”—chemicals responsible for deteriorating air quality. These included smoke, dust, ash, particulates, fumes, and mist, generated by fuel combustion, electrical heating, synthesis, and decomposition processes. These compounds were harmful to both the environment and human health. Construction sites featured various processes and activities. In Malaysia, construction operations impacted the environment, natural resources, and public health by 67.5%, 21.0%, and 11.5%, respectively [20]. Many site activities especially earthworks like excavation, produced dust. Other activities included drilling, bulk material transport, loading and unloading, outdoor storage, and cutting and filling, which contributed to dust emissions during equipment movement.

Several engineering controls were employed to reduce air pollution, including water spraying, installing wind barriers, and using dust collectors. These measures effectively reduced dust and solid particles generated during construction. According to research, Malaysia currently employed wet work methods to limit airborne dust in compliance with Department of Environment (DOE) regulations. In contrast, the Tokyo Metropolitan Government enforced stricter measures, such as mandatory dust collectors and water spraying, which successfully minimized construction-related dust [21]. Hence, engineering controls like water spraying and dust collection could significantly reduce air pollution from construction activities.

3.5. Energy efficiency.

According to research [30], Malaysia's population was expected to rise from 32.7 million in 2022 to 36.09 million by 2030 and 40.55 million by 2050. This population growth would significantly increase the nation's energy demands. As of 2020, Malaysia's primary energy supply comprised 39.0% natural gas, 33.8% crude oil and petroleum products, 23.5% coal, and only 3.9% renewable energy. This indicated that renewable energy made up a relatively small portion of the energy mix. Although the renewable energy industry had progressed beyond its early development stages, competition remained strong. Given its heavy reliance on fossil fuels, Malaysia urgently needed sustainable alternatives to ensure long-term energy security as these resources diminished. Renewable sources such as solar energy, wind energy, and hydropower were already contributing to the national grid. Among these, solar photovoltaic systems were especially desirable due to their abundant availability and low maintenance. Malaysia received high levels of solar radiation, ranging from 10.99 to 17.91 MJ/m²/day [22]. Since the construction industry consumed a large amount of energy, integrating solar energy into construction projects could reduce energy use, lower costs, and support environmental sustainability [23].

4. Green Materials and Advanced Technologies for Sustainability in Construction

Green materials and advanced technologies play a critical role in improving the environmental performance of construction. These materials such as recycled plastic, bamboo, cork, recycled wood and steel, reduce resource consumption and environmental impact across a building's life cycle. Meanwhile, advanced technologies like Building Information Modeling (BIM), prefabrication, and smart energy systems help optimize design, minimize waste, and improve energy efficiency. Together, they support the shift toward sustainable construction by lowering carbon emissions, reducing water and energy use, and improving indoor environmental quality. Figure 2 presents a visual summary of these materials and technologies and how they contribute to greener construction practices.

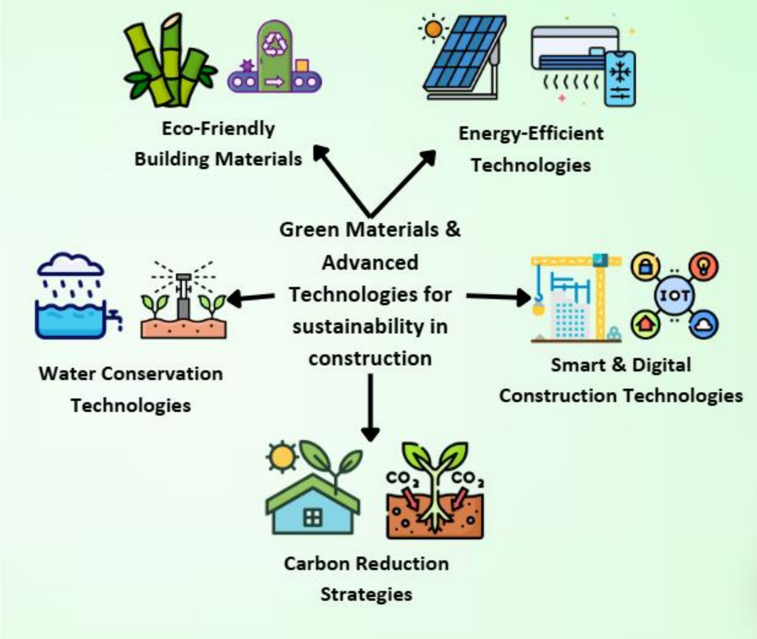

Figure 2. Green materials and advanced technologies to enhance sustainability in construction.

4.1. Eco-friendly building materials.

The use of environmentally friendly construction materials has grown in popularity across various sectors due to legislative requirements related to environmental preservation. The packaging and disposable tableware industries, which generated the greatest amount of waste in a short period, necessitated the rapid adoption of an increasing number of ecological solutions. In this context, the use of biodegradable materials was fully justified, as they contained residues from food products and waste collected for organic recycling. In addition to the extensive use of disposable materials, such as mulch foil for protecting crops and boosting yield, agriculture also created opportunities for biodegradable materials. However, applying biodegradable polymers to building materials remained challenging when weather resistance and durability were required [24]. Biodegradation was considered a beneficial property, especially for finishing materials like flooring. Furthermore, buildings such as restaurants and hotels required periodic renovation to maintain their aesthetics, which created new opportunities for the use of biomaterials. Biodegradable polymers could be employed as biomaterials, as well as composites in which they served as a matrix. The use of fillers in biodegradable polymers played a crucial role in reducing costs and enhancing other properties of the resulting composites. Thus, the use of eco-friendly construction materials helped conserve waste and protect the environment [25]. Table 2 shows examples of eco-friendly construction materials used to safeguard the environment.

4.2. Electrification of construction machinery.

Electrifying transportation was a crucial step in achieving carbon neutrality. Similar advancements in electric construction machinery (ECM) were recently made due to the rapid adoption of electric vehicles and the progress of electrification technologies. Previous research mainly focused on improving the operating energy efficiency of individual electric construction machinery by developing hybrid energy storage units, optimizing powertrain ratios, and proposing suitable energy management strategies [29]. However, given the current limitations of battery technology, charging time remained relatively short. Consequently, it was more practical to focus on scheduling the electric construction equipment collaborative system (ECMCS) rather than maximizing the energy efficiency of each machine independently to encourage widespread adoption of electric construction machinery. Thus, electrical construction machinery helped reduce energy consumption, improve building construction, and promote a sustainable environment [30].

Table 2. Examples of eco-friendly building materials [26–28].

Material	Benefits	Challenges
Bamboo	- Rapidly renewable; grows much faster than timber (3–5 years) - High strength-to-weight ratio - Lightweight and easy to transport - Biodegradable and eco-friendly	- Susceptible to pests, moisture, and decay without proper treatment - Limited code acceptance in some regions - Requires skilled handling
Cork	- Renewable (harvested without cutting down the tree) - Naturally fire-resistant, water-resistant, and sound-absorbing - Lightweight and elastic	- Limited structural use - Higher cost compared to conventional insulation - Limited supply outside Mediterranean regions
Recycled Plastic	- Diverts plastic waste from landfills - Moisture-resistant and durable - Low maintenance - Versatile in applications (composite lumber, panels, etc.)	- May release toxins if not properly processed - Limited load-bearing capacity - Risk of microplastic pollution during wear and tear
Recycled Wood	- Reduces deforestation and landfill waste - Often cheaper than new wood - Aesthetic value with aged textures - Can be repurposed in multiple applications	- May contain nails, adhesives, or old coatings - Inconsistent quality - Requires time-consuming inspection and preparation
Recycled Steel	- Infinite recyclability without loss of quality - High durability and structural integrity - Saves up to 75% of energy compared to virgin steel - Fire and pest resistant	- High embodied energy compared to natural materials - May be more expensive upfront - Requires precision tools and skilled labor

4.3. Smart and digital construction technologies.

The digitalization lifecycle in construction has been increasing for over 20 years. The primary impact of digitalization was the provision of enhanced mechanisms for data and information management and security. BIM is one such smart and digital construction technology. BIM provides a multi-accessible 3D digital modeling platform for constructed assets, serving as an IT-oriented tool to share, store, and manage building information. Research showed the benefits of combining BIM and the IoT to facilitate automated solutions in smart buildings [31]. This integration of BIM and IoT was described as a novel procedure because BIM software combined current and future smart building features with IoT, which could optimize humidity and temperature. Additionally, BIM helped address several smart city issues, such as traffic congestion, climate change, and smart road maintenance. IoT connected products to better serve unique consumer demands and collected data to support the development of more interconnected systems and subsystems. Research also highlighted that IoT provided an interdisciplinary approach to building energy efficiency [32]. Thus, using smart and digital construction technologies like BIM and IoT improved environmental outcomes [33].

4.4. Carbon reduction strategies.

Global warming became a significant environmental issue due to worldwide development in the early 21st century. Research acknowledged that human activities were responsible for the gradual rise in temperature. Greenhouse gas emissions were the key contributors, with high concentrations of carbon dioxide (CO_2) accounting for about 60% of these emissions [34]. These emissions worsened the ecosystem's condition. Therefore, carbon emissions could be reduced by recycling building waste. For example, scrap metal could be recycled directly at steel processing facilities for immediate reuse. Scrap concrete was used as foundation reinforcement and as raw material for recycled aggregate. Additionally, renewable energy sources such as solar energy could be used for electricity, especially since Malaysia receives high levels of sunlight, which promoted sustainability in construction. Reforestation also played a role in carbon storage by restoring deforested areas and reducing carbon emissions. Research stated that reforestation increased sequestration effectiveness by up to 30%, improving carbon management [35]. Thus, using eco-friendly materials, renewable energy, and reforestation helped reduce carbon emissions and supported environmental sustainability in construction.

4.5. Water conservation technologies.

A green building was defined as a construction that used resources efficiently while minimizing negative environmental impacts and maximizing resource use such as water and energy. Many advanced technologies were implemented, including solar panels, green roofs, rain gardens, rainwater harvesting, and greywater recycling and reuse. Freshwater resources were limited for daily human use. With the global population currently around 6.7 billion and growing by approximately 80 million per year, freshwater demand was increasing. This implied a 64 billion cubic meter annual rise in freshwater needs. The UN estimated that by 2050, 5 billion people (two-thirds of the population) would face limited access to clean freshwater, highlighting the urgent need for water conservation [36]. One effective technology for conserving water was rainwater harvesting, which reduced flooding and soil erosion. Rainfall was collected by diverting it from roofs into underground or above-ground storage tanks. After filtration, the harvested rainwater was pumped directly to appliances for use, thus conserving water in construction. Another water conservation method was the use of greywater, which came from sinks, toilets, and showers. The greywater method was particularly suitable for construction, which consumed significant water volumes. By reusing greywater, the construction sector could conserve water and promote sustainability [37].

5. Sustainable Construction Policies, Measures and Incentives in Malaysia

Sustainable development initiatives have been actively pursued worldwide. To achieve national policy goals including reducing environmental impact, enhancing energy efficiency, and ensuring energy security to meet growing demand, the Malaysian government has formulated key policies and plans for over 30 years. Malaysia is currently focusing on developing effective renewable energy regulations to reduce reliance on fossil fuels and mitigate climate change. Although Malaysian renewable energy projects have taken considerable time to materialize, the government has encouraged the use of renewable energy through legislation. Table 3 summarizes the Malaysia Plans from the 7^{th} to the 10^{th}, highlighting energy development. The 7th, 8th, and 9th Malaysia Plans emphasized sustaining depletable and energy resources. However, the 10th Malaysia Plan introduced the National Green Technology Policy and increased public awareness regarding the application of green technologies for sustainable development [38].

Following the 1970s energy crisis, Malaysia implemented the "Four-Fuel Diversification Strategy" in 1980 to address energy security concerns. This strategy included expanding hydropower and promoting non-renewable energy sources such as natural gas to reduce dependence on oil. The fifth-fuel strategy was introduced in the 8th Malaysia Plan to promote renewable energy use and address rising global climate change concerns. Despite slow progress, the government continued to strengthen the use of renewable energy and biomass resources from oil palm and other sources for electricity generation under the 9th Malaysia Plan. However, grid-connected power generation from Small Renewable Energy Power projects contributed only 56.7 MW of renewable energy to the nation's total energy mix after the 9th Malaysia Plan. Therefore, Malaysia has actively pursued increasing renewable energy's share under the 10th Malaysia Plan, which targeted generating 985 MW by 2015, accounting for 5.5% of the overall power output. Following this, the National Renewable Energy Policy 2010 was introduced, alongside the Renewable Energy Policy 2010 and Action Plan. These policies aimed to expand renewable energy utilization to support sustainable construction development in Malaysia [39].

Table 3. Malaysia plan from 7th to 10th for energy development.

Malaysia Plan	Key emphasis	References
Seventh Malaysia Plan (1996-2000)	– Sustainable development and depletable resources – Ensure the adequacy of generating efficiency – Encouraged the use of new and alternative energy sources and the efficient utilisation of energy	[40]
Eight Malaysia Plan (2001-2005)	– Sustainable development and depletable resources – Ensure the adequacy of generating efficiency – Encourage the efficient utilisation of gas and renewable energy for electricity – Supports the development of industries in the production of energy	[41]
Ninth Malaysia Plan (2006-2010)	– Strengthening initiatives for energy efficiency in the transport, commercial and industrial areas – Encourage better utilisation of renewable energy – Further reducing the dependency on petroleum	[40]
Tenth Malaysia Plan (2011-2015)	– Short-term goals vested in National Green Technology policy – Increased public awareness and commitment to the adoption and application of green technology – Widespread availability and recognition of green technology – Increased foreign and domestic direct investment in green technology manufacturing areas	[41]

6. Major Challenges of Implementing Sustainable Construction in Malaysia

Adopting the sustainability movement offers many advantages, but significant obstacles still hinder its widespread and rapid acceptance in Malaysia's construction sector. Table 4 outlines the challenges of implementing sustainable construction in Malaysia. The three main obstacles are lack of awareness, insufficient information and understanding, and the high cost of implementing green practices. Most Malaysian stakeholders continue to believe that adopting green practices requires expensive materials, resources, technology, and skilled labor. Additionally, stakeholders perceive that because Malaysia does not produce high-quality green products domestically, it must import green technology, which drives up costs. Furthermore, stakeholders agree that sustainable initiatives are risky investments due to their longer payback periods.

The second major obstacle is the limited awareness among stakeholders in Malaysia's construction industry about the green movement. Although sustainability and green initiatives have existed since the 1900s, the construction sector still lacks sufficient knowledge about green practices. This gap exists because knowledge is crucial for raising public awareness and advancing society. Consequently, the third key challenge is the general lack of understanding about the green energy movement within Malaysia's building sector. Research [42] indicates that most developing countries fail to adequately educate and train construction stakeholders, which impedes the wider adoption of sustainable building practices. Therefore, this finding aligns with the study's results, and the government should take responsibility and play a proactive role in educating and raising awareness among all parties involved in green practices [6].

Table 4. Challenges of implementing sustainable construction in Malaysia.

Category	Challenges	References
Cost	– Lack of financial resources	[43]
	– High maintenance cost	[44]
	– Risk of investment	[45]
	– Cost of importing products	[46]
Information and Awareness	– Lack of awareness	[43]
	– Fear of changes	[44]
	– Insufficient information and knowledge	[45]
	– Uncertainties	[46]
Workforce	– Lack of expertise	[43]
	– Insufficient supply of green products	[44]
	– Lack of sustainable machinery and equipment criteria selection	[45]
	– Poor welfare	[46]
Market and Demand	– Lack of demand and interest	[43]
	– High market prices	[44]
	– Lack of research and development	[45]
	– Negative perception	[46]
Government	– Insufficient government support	[43]
	– Lack of enforcement	[44]
	– Insufficient guidelines and policies	[45]
	– Lack of government incentives	[46]
Time	– Longer construction time	[45]

7. Future Challenges and Prospects

The capacity to complete a green project within realistic budgetary and schedule restrictions was one of the many obstacles facing sustainable practices, especially in green construction. Since project management was responsible for duties including planning, cost estimation, and high-quality completion, it had a significant impact on whether the project succeeded or failed. This was because productivity directly affected construction project time and costs, which could improve various aspects of sustainability by reducing building project time and expenses. One of the key success factors for executing renewable energy projects was cost and time.

Green building projects were challenging, and as a result, they struggled to effectively and efficiently manage the project. This was especially crucial in emerging nations where funds could be allocated to the advancement of other institutions and technologies. Utilizing renewable energy could lower carbon dioxide emissions and support Malaysia’s long-term alternative energy sources. Therefore, additional funding was required to properly implement this alternative. Moreover, construction projects could have long-term impacts on the environment, economy, and society. The selection and monitoring of a portfolio had to comply with sustainable development principles. Sometimes, it was challenging to put these costs and contributions into monetary terms or to quantify them [47].

According to research [48], sustainability in project management referred to the completion of projects backed by planning, monitoring, and control systems that took social, economic, and environmental factors into account. Because project management had a major impact on project performance, research indicated that implementing Project Management Practices (PMPs) was key to more sustainable construction. The expertise and experience of project managers highlighted their significant influence on the adoption of sustainability. The effectiveness of renewable energy projects was greatly influenced by elements including stakeholder involvement and risk management. The decisions made by managers had the power to shape a construction project toward sustainable construction. However, a common obstacle to the broad adoption of sustainable methods was the lack of education and training in the construction industry [49].

Engaging stakeholders was essential because it ensured that all opinions were heard and issues were resolved. By promoting knowledge exchange, this strategy enabled stakeholders to benefit from one another’s best practices and experiences. Furthermore, a collaborative approach facilitated open communication when sustainability-related issues could impede project advancement. Additionally, a well-managed sustainable project helped move away from the traditional strategy, which addressed only environmental deterioration, toward the creation of a constructed environment. A good sustainable project emphasized the necessity of seeking context-specific design solutions for a nature-built ecosystem that coexisted peacefully. Leaving the planet in a better state for future generations was beneficial for environmental sustainability. This could be applied by using renewable energy such as solar power and recycling to sustain, rather than harm, the environment [50].

Sustainable project management was greatly influenced by technological developments addressing environmental, social, and economic problems. Data analytics and monitoring were two important areas where technology played a critical role. Project managers could process and analyze data on a project’s social and environmental effects through technology. It could track and evaluate sustainability performance in real time, offering insightful information that helped with decision-making. For example, an IoT device could track energy consumption to reduce negative environmental impacts. Additionally, the use of BIM technology in construction projects enabled project teams to design by generating digital models of buildings and infrastructure. This allowed early identification of sustainability concerns, such as material waste, and encouraged environmentally friendly design [51].

8. Development of approval processes in Malaysia and comparison with international best practices

Figure 3 shows the development approval processes in Malaysia. Firstly, developers need to prepare a project proposal to provide a synopsis of the project's specifics and pitch to the stakeholders to encourage their participation and land acquisition for the purpose of construction. After that, developers must submit their plans to the local planning authority for approval. Planning approval is a permit that must be obtained before constructing any building or developing land. This is to ensure that the plans and laws of the town comply with the development. Environmental Impact Assessment (EIA) is required for some project development [52]. This is to evaluate the development proposal's major environmental impacts. EIA ensure that the potential environmental impacts will be lessen as soon as feasible. Table 5 shows some of the environmental impacts in the construction area. After that, developers must submit the building plan approval and technical approval that includes architectural, engineering plans, and technical and structural review. A developer must submit all pertinent plans and documentation to the local authorities in order to meet all the criteria for development and safety. After the building plan and technical approval have been approved and obtained, the local authorities will issue a construction permit so that the developer is legal to start the construction project. The purpose of the construction permit is to provide safety to high-risk jobs. Developers must always make regular monitoring to ensure the safety, environmental and structural standards are complied with in the construction phase. Next, the government will do a final inspection when the construction phase is finished and a certificate of Completion and Compliance (COC) will be granted if the safety and compliance with regulations of the building are satisfied. Additionally, a final inspection aids in resolving any problems and issues that can compromise the projects's completion. The building can be legally occupied and turned over to the renters, owners and other pertinent stakeholders once a certificate of COC has been obtained. People will benefit from this as there will be more job opportunities and the economy of Malaysia will be more stabilize [53].

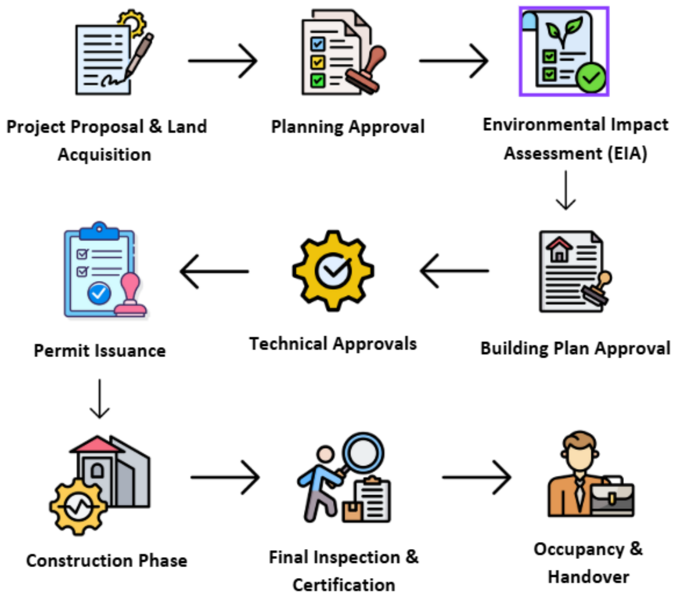

Figure 3. Development approval processes in malaysia.

Table 5. Environmental impacts of the construction area.

Environmental Impact	Factor	Effects	References
Water Pollution	– Sediment runoff – Improper waste disposal	– Harm to aquatic life	[54]
Air Pollution	– Dust from types of machinery like excavators	– Poor air quality	[55]
Construction Waste	– Inefficiency of resources	– Depletion of resources	[56]
Noise Pollution	– Sound from types of machinery like excavators and other heavy machinery operations	– Hearing damage to people near the construction area	[57]

Malaysia's and international's best practices in development approval processes are different. Malaysia has multiple stages of development approval processes such as planning proposal, building plan approval, Environmental Impact Assessment, project proposal and others meanwhile International also has multiple stages but are simplified to minimize the delays by cutting down the stages. Malaysia has various agencies like the DOE, Land Office and other agencies meanwhile for International, they are centralized systems. International processing time is faster than in Malaysia [58]. Besides that, some projects are required for EIA in Malaysia whereas in International it is more stringent carbon footprint calculations and sustainability laws. There is limited public involvement in Malaysia compared to International. Malaysia also uses manual submission but sometimes digital initiatives in cities whereas internationally uses advanced e-permitting systems and AI-assisted planning approvals. Green Building Index (GBI) certification is encouraged but not mandatory meanwhile International enforces strict green building policies. Some concerns about delays and inefficiency in systems for Malaysia whereas International uses transparency laws and online tracking to reduce the corruption risks [59].

5. Conclusions

Sustainable construction practices face numerous challenges, particularly in emerging economies like Malaysia, where cost, awareness, and expertise remain significant barriers. Effective project management plays a crucial role in overcoming these challenges by ensuring green projects are completed within budget and schedule, thereby enhancing productivity and sustainability outcomes. The integration of renewable energy, such as solar power, alongside recycling and eco-friendly technologies, contributes to reducing carbon emissions and supporting Malaysia's long-term environmental goals. Technological advancements, including IoT and BIM, further facilitate sustainability by enabling real-time monitoring, efficient resource use, and early detection of environmental concerns. Malaysia's development approval process, involving planning, environmental impact assessments, and strict regulatory compliance, helps ensure construction projects align with sustainable development principles. However, the slow adoption of green practices is partly due to limited knowledge and training within the construction sector, highlighting the need for increased education and stakeholder engagement. Collaborative approaches that encourage knowledge exchange and open communication are essential to advancing sustainability efforts. Ultimately, sustainable construction requires coordinated efforts from project managers, government authorities, and industry stakeholders to balance environmental, social, and economic factors. By embracing these principles and technologies, Malaysia can promote sustainable development, improve construction outcomes, and contribute to global environmental goals.

Author Contributions

Aimie Peace Siganul: writing original draft preparation; Surya Dewi Puspitasari: Conceptualization, methodology, formal analysis.

Funding

This research received no external funding.

Data Availability Statement

This review article is based on previously published studies and publicly available information. No new experimental data were generated or analyzed during the course of this study. All referenced data can be found in the cited sources.

Acknowledgements

The authors would like to acknowledge the support and resources provided by the Curtin University Malaysia, and Norwegian University of Science and Technology Norway. Their facilities and academic environment have been invaluable for the completion of this research.

Competing Interest

The authors declare that there are no competing interests associated with this study.

References

[1] Ezema, I.C. (2019). Materials. *Sustainable Construction Technology*, *237*, 237–262. https://doi.org/10.1016/b978-0-12-811749-1.00007-9.

[2] Cubukcuoglu, B. (2022). The Importance of Environmental Sustainability in Construction. *Risk Reliability Sustainability Remediation*, *249*, 249–254. https://doi.org/10.1016/b978-0-323-85698-0.00014-9.

[3] Malaysia committed to SDG, Paris Agreement 2015 objectives. accessed on Day Month Year) Available online: https://www.mida.gov.my/mida-news/malaysia-committed-to-sdg-paris-agreement-2015-objectives/.

[4] Wong, J.H.; Rashidi, A.; Arashpour, M. (2020). Evaluating the Impact of Building Information Modeling on the Labor Productivity of Construction Projects in Malaysia. *Buildings*, *10*, 66. https://doi.org/10.3390/buildings10040066.

[5] Daly, M.; Kempton, L.; McCarthy, T. (2025). Sustainability of prefabricated construction in Australia: Industry perspectives on challenges and opportunities. *Journal of Building Engineering*, *102*, 111805. https://doi.org/10.1016/j.jobe.2025.111805.

[6] Masyhur, R.T.; Alias, A.H.; Haron, N.A.; Zulkafli, Z. (2024). A systematic review on green practices in the Malaysian construction industry: Status, challenges, key motivations, rating systems and technology evolution. *Energy and Buildings*, *320*, 114550. https://doi.org/10.1016/j.enbuild.2024.114550.

[7] Musarat, M.A.; Alaloul, W.S.; Binti, M.; Qureshi, A.H.; Maqsoom, A. (2024). Digitalization in Malaysian construction industry: Awareness, challenges and opportunities. *Results in Engineering*, *21*, 102013. https://doi.org/10.1016/j.rineng.2024.102013.

[8] Ibrahim, A.R.; Roy, M.H.; Ahmed, Z.; Imtiaz, G. (2010). An investigation of the status of the Malaysian construction industry. *Benchmarking*, *17*, 294–308. https://doi.org/10.1108/14635771011036357.

[9] Ha, C.Y.; Khoo, T.J.; Koo, Z.Y. (2023). Current status of green building development in Malaysia. *Progress in Energy and Environment*, 25, 1–9. https://doi.org/10.37934/progee.25.1.19.

[10] Rizvi, L.; Griffin, K.; Zytaruk, N.; Cook, D.J.; Sykes, J.; Burns, K.E.A. (2023). International variation in ethics and contract approval processes for a low-risk observational study of mechanical ventilation discontinuation practices. *Journal of Clinical Epidemiology*, *164*, 27–34. https://doi.org/10.1016/j.jclinepi.2023.10.006.

[11] Low, W.W.; Abdul-Rahman, H.; Zakaria, N. (2018). Organisational culture of Malaysian international construction organisations. *International Journal of Construction Management*, *20,* 105–121. https://doi.org/10.1080/15623599.2018.1484552.

[12] Meng, X. (2012). The effect of relationship management on project performance in construction. *International Journal of Project Management*, *30,* 188–198. https://doi.org/10.1016/j.ijproman.2011.04.002.

[13] Abdullah, M.; Yunus, R.; Gamil, Y.; Albaom, M.A. (2024). Enhancing construction site performance through technology and management practices as material waste mitigation in the Malaysian construction industry. *Heliyon*, *10,* e28721. https://doi.org/10.1016/j.heliyon.2024.e28721.

[14] Fountoulakis, M.S.; Markakis, N.; Petousi, I.; Manios, T. (2016). Single house on-site grey water treatment using a submerged membrane bioreactor for toilet flushing. *Science of the Total Environment*, *551–552,* 706–711. https://doi.org/10.1016/j.scitotenv.2016.02.057.

[15] Ong, Z.C.; Asadsangabifard, M.; Ismail, Z.; Tam, J.H.; Roushenas, P. (2019). Design of a compact and effective greywater treatment system in Malaysia. *Desalination and Water Treatment*, *146,* 141–151. https://doi.org/10.5004/dwt.2019.23631.

[16] Lastra-González, P.; Calzada-Pérez, M.A.; Castro-Fresno, D.; Vega-Zamanillo, Á.; Indacoechea-Vega, I. (2016). Comparative analysis of the performance of asphalt concretes modified by dry way with polymeric waste. *Construction and Building Materials*, *112,* 1133–1140. https://doi.org/10.1016/j.conbuildmat.2016.02.156.

[17] Al-Hadidy, A.I. (2018). Effect of laboratory aging on moisture susceptibility and resilient modulus of asphalt concrete mixes containing PE and PP polymers. *Karbala International Journal of Modern Science*, *4,* 377–381. https://doi.org/10.1016/j.kijoms.2018.10.001.

[18] Khan, S.; Li, H.; Ncube, M.H.; Butt, A.A.; Han, Y.; Harvey, J. (2025). Environmental implications of recycled materials in pavement construction: A comprehensive review and future research directions. *Transportation Research Part D: Transport and Environment*, *140,* 104642. https://doi.org/10.1016/j.trd.2025.104642.

[19] Department of Environment. (accessed on 24 March 2025) Available online: https://govdocs.sinarproject.org/documents/ministry-of-natural-resources-and-environment/department-of-environment.

[20] Zolfagharian, S.; Nourbakhsh, M.; Irizarry, J.; Ressang, A.; Gheisari, M. (2012). Environmental impacts assessment on construction sites. *Construction Research Congress*. https://doi.org/10.1061/9780784412329.176.

[21] Fan, G.; Linlin, L.; Huang, R.; Shihang, L.; Shi, W.; Binbin, C.; Peng, Z.; Xia, Y. (2025). Dust removal process of the multi-filter cartridges and its optimization measures for coal dust pollution: Experimental and numerical investigations. *Journal of Environmental Chemical Engineering*, *13,* 115715. https://doi.org/10.1016/j.jece.2025.115715.

[22] Affandi, N.A.A.; Ludin, N.A.; Junedi, M.M.; Phoumin, H. (2025). Transitions to low carbon distributed energy systems in Malaysia: Environmental, economics and policy implications. *Renewable Energy*, *242*, 122444. https://doi.org/10.1016/j.renene.2025.122444.

[23] Hamed, A.S.A.; Yusof, N.I.F.M.; Yahya, M.S.; Cardozo, E.; Munajat, N.F. (2023). Concentrated solar pyrolysis for oil palm biomass: An exploratory review within the Malaysian context.

Renewable and Sustainable Energy Reviews, *188*, 113834. https://doi.org/10.1016/j.rser.2023.113834.
[24] Dong, Y.; Lan, J.; Zang, M.; Lu, H.; Zhang, D.; Huang, B.-T. (2024). Eco-friendly preparation of self-bonding materials from natural aeolian sand and secondary aluminum dross for sustainable desert construction. *Journal of Cleaner Production*, *483*, 144214. https://doi.org/10.1016/j.jclepro.2024.144214.
[25] Musioł, M.; Ranote, S.; Sikorska, W.; Duale, K.; Kowalczuk, M. (2024). Eco-friendly biodegradable materials for industrial and building applications. Elsevier eBooks. https://doi.org/10.1016/b978-0-443-15738-7.00045-3.
[26] Yadav, M.; Mathur, A. (2021). Bamboo as a sustainable material in the construction industry: an overview. *Materials Today: Proceedings*, *43*, 2872–2876. https://doi.org/10.1016/j.matpr.2021.01.125.
[27] Salah, A.; Nada, S.; Mahmoud, H. (2024). Applicability of developing an affordable eco-friendly switchable insulation for sustainable building envelopes in a hot climate: Comprehensive review. *Energy and Buildings*, *323*, 114757. https://doi.org/10.1016/j.enbuild.2024.114757.
[28] Keçili, R.; Hussain, G.; Hussain, C.M. (2025). Nano-engineered eco-friendly materials for food safety: Chemistry, design and sustainability. *Food Chemistry*, *465*, 141906. https://doi.org/10.1016/j.foodchem.2024.141906.
[29] Carlander, J.; Thollander, P. (2022). Barriers to implementation of energy-efficient technologies in building construction projects – results from a Swedish case study. *Resources, Environment and Sustainability*, *11*, 100097. https://doi.org/10.1016/j.resenv.2022.100097.
[30] Huang, X.; Yan, W.; Tao, G.; Chen, S.; Cao, H. (2024). Energy-efficient configuration and scheduling framework for electric construction machinery collaboration systems. *Automation in Construction*, *168*, 105808. https://doi.org/10.1016/j.autcon.2024.105808.
[31] Luo, H. (2025). Does smart city construction exacerbate capital misallocation? Spatial spillovers, digital transformation, and robotics application. *Structural Change and Economic Dynamics*, *73*, 328–344. https://doi.org/10.1016/j.strueco.2025.01.008.
[32] Hasibuan, G.C.R.; Al Fath, M.T.; Yusof, N.; Dewi, R.A.; Syafridon, G.G.A.; Jaya, I.; Anas, M.R. (2025). Integrating circular economy into construction and demolition waste management: a bibliometric review of sustainable engineering practices in the built environment. *Case Studies in Chemical and Environmental Engineering*, *11*, 101159. https://doi.org/10.1016/j.cscee.2025.101159.
[33] Mayouf, M.; Afsar, F.; Iqbal, A.; Javidroozi, V.; Mohandes, S.R. (2024). Synergies between digital construction technologies in smart buildings and smart city development to meet building users' expectations. *Heliyon*, *10*, e28585. https://doi.org/10.1016/j.heliyon.2024.e28585.
[34] Meng, Q.; Hu, L.; Li, M.; Qi, X. (2023). Assessing the environmental impact of building life cycle: a carbon reduction strategy through innovative design, intelligent construction, and secondary utilization. *Developments in the Built Environment*, *16*, 100230. https://doi.org/10.1016/j.dibe.2023.100230.
[35] Wong, P.S.P.; Zapantis, J. (2013). Driving carbon reduction strategies adoption in the Australian construction sector – the moderating role of organizational culture. *Building and Environment*, *66*, 120–130. https://doi.org/10.1016/j.buildenv.2013.04.022.
[36] Niu, T.; Hou, Z.; Yu, J.; Lu, J.; Yu, Q.; Yang, L.; Ma, J.; Liu, Y.; Shi, H.; Jin, X. (2024). Construction of prediction model for water retention of forest ecosystem in alpine region based on vegetation spectral features. *Ecological Indicators*, *169*, 112889. https://doi.org/10.1016/j.ecolind.2024.112889.
[37] Li, A.; Yang, Y.; Wu, S.; Wu, T.V.; Zhang, Y.; Wu, W.; Zhang, H. (2025). Study on non-destructive detection technology of water content and defects in construction materials based on

transmission terahertz system. *Journal of Building Engineering*, *104*, 112452. https://doi.org/10.1016/j.jobe.2025.112452.

[38] Chua, S.C.; Oh, T.H. (2010). Review on Malaysia's national energy developments: Key policies, agencies, programmes and international involvements. *Renewable and Sustainable Energy Reviews*, *14*, 2916–2925. https://doi.org/10.1016/j.rser.2010.07.031.

[39] Mustapa, S.I.; Leong, Y.P.; Hashim, A.H. (2010). Issues and challenges of renewable energy development: A Malaysian experience. *Proceedings of the International Conference on Energy and Sustainable Development*. https://doi.org/10.1109/esd.2010.5598779.

[40] Hashim, H.; Ho, W.S. (2011). Renewable energy policies and initiatives for a sustainable energy future in Malaysia. *Renewable and Sustainable Energy Reviews*, *15*, 4780–4787. https://doi.org/10.1016/j.rser.2011.07.073.

[41] Shirley, R.; Kammen, D. (2015). Energy planning and development in Malaysian Borneo: Assessing the benefits of distributed technologies versus large scale energy mega-projects. *Energy Strategy Reviews*, *8*, 15–29. https://doi.org/10.1016/j.esr.2015.07.001.

[42] Ogunmakinde, O.E.; Egbelakin, T.; Sher, W.; Omotayo, T.; Ogunnusi, M. (2023). Establishing the limitations of sustainable construction in developing countries: A systematic literature review using PRISMA. *Smart and Sustainable Built Environment*, *13*, 609–624. https://doi.org/10.1108/sasbe-10-2022-0223.

[43] Wayne, T.; Chai, C.S.; Wong, S.S.L.; Lim, F.L.; Goh, K.C.; Abidin, N.I. (2023). Evaluation of digital's role in sustainable built environment. *Pertanika Journal of Science and Technology*, *31*, 1335–1351. https://doi.org/10.47836/pjst.31.3.13.

[44] Zulkefli, N.S.; Mohd-Rahim, F.A.; Zainon, N. (2020). Integrating building information modelling (BIM) and sustainability to greening existing building: Potentials in Malaysian construction industry. *International Journal of Sustainable Construction Engineering and Technology*, *11*, 76–93. https://doi.org/10.30880/ijscet.2020.11.03.008.

[45] Singh, C.S. (2018). Green construction: Analysis on green and sustainable building techniques. *Civil Engineering Research Journal*, *4*, 555638. https://doi.org/10.19080/cerj.2018.04.555638.

[46] Saha, A.; Kulkarni, N.D.; Kumari, P. (2024). Development of Bambusa tulda fiber-micro particle reinforced hybrid green composite: A sustainable solution for tomorrow's challenges in construction and building engineering. *Construction and Building Materials*, *441*, 137486. https://doi.org/10.1016/j.conbuildmat.2024.137486.

[47] Jiang, Y.; Su, S.; Zhao, S.; Zhong, R.Y.; Qiu, W.; Skibniewski, M.J.; Brilakis, I.; Huang, G.Q. (2024). Digital twin-enabled synchronized construction management: a roadmap from Construction 4.0 towards future prospect. *Developments in the Built Environment*, *100512*, 100512. https://doi.org/10.1016/j.dibe.2024.100512.

[48] Mahjoub, B.; Fersi, C.; Bouteffeha, M.; Kummerer, K. (2025). Green chemistry and sustainable chemistry related to water challenges: solutions and prospects in a changing climate. *Current Opinion in Green and Sustainable Chemistry*, *52*, 101000. https://doi.org/10.1016/j.cogsc.2025.101000.

[49] Chen, L.; Yang, M.; Chen, Z.; Xie, Z.; Huang, L.; Osman, A.I.; Farghali, M.; Sandanayake, M.; Liu, E.; Ahn, Y.H.; et al. (2024). Conversion of waste into sustainable construction materials: a review of recent developments and prospects. *Materials Today Sustainability*, *27*, 100930. https://doi.org/10.1016/j.mtsust.2024.100930.

[50] Hasan, K.; Jaya, R.P.; Yahaya, F.M. (2024). Application of bentonite in cement-based composites: a review of current status, challenges and future prospects. *Journal of Building Engineering*, *98*, 111171. https://doi.org/10.1016/j.jobe.2024.111171.

[51] Rahaman, T.; Khan, S.H. (2024). Green merchandising of textiles and apparel in a circular economy: recent trends, framework, challenges and future prospects towards sustainability.

Journal of Open Innovation: Technology, Market, and Complexity, *11*, 100457. https://doi.org/10.1016/j.joitmc.2024.100457.

[52] Devadas, S.; Zakaria, Z.; Din, M.S.M.; Bhassu, S.; Karim, M.M.A.; Ikhsan, N.; Rahman, A.B. (2025). Knowledge, attitudes and practices on antimicrobial use and antimicrobial resistance among shrimp aquaculturists in Peninsular Malaysia. *Preventive Veterinary Medicine*, *239*, 106513. https://doi.org/10.1016/j.prevetmed.2025.106513.

[53] Sa'adi, Z.; Alias, N.E.; Yusop, Z.; Mei, N.S.; Wai, C.W.; Arman, N.Z.; Tajuddin, W.A.N.W.A.; Ramzan, M.A.; Aris, A.; Talib, J.; et al. (2025). Enhancing climate change-induced flood co-adaptation in the Johor River Basin, Malaysia: a dotmocracy mapping approach with key technical stakeholders. *Environmental Science and Policy*, *165*, 104015. https://doi.org/10.1016/j.envsci.2025.104015.

[54] Arash, M.O.T.A.L.E.B.I.; Hasan, M.A.H.K.; Kabir, G. (2025). Assessing the environmental impact of building houses in remote areas: 3D printing vs. traditional construction techniques. *Journal of Building Engineering*, *102*, 111968. https://doi.org/10.1016/j.jobe.2025.111968.

[55] Fang, X.; Chang, R.; Zuo, J.; Zhang, W.E.; Zou, Y.; Li, K. (2025). How do environmental and operational factors impact particulate matter dynamics in building construction? - Insights from real-time sensing. *Journal of Environmental Management*, *380*, 125098. https://doi.org/10.1016/j.jenvman.2025.125098.

[56] Luttenberger, L.R.; Ančić, I.; Luttenberger, A. (2025). Environmental impact assessment procedure in transport construction projects. *Transportation Research Procedia*, *83*, 554–560. https://doi.org/10.1016/j.trpro.2025.03.025.

[57] Yu, Z.; Nurdiawati, A.; Kanwal, Q.; Al-Humaiqani, M.; Al-Ghamdi, S.G. (2024). Assessing and mitigating environmental impacts of construction materials: insights from environmental product declarations. *Journal of Building Engineering*, *98*, 110929. https://doi.org/10.1016/j.jobe.2024.110929.

[58] Dhief, I.; Wang, Z.; Zhou, W.; Alam, S.; Stahnke, A.; Losensky, L.; Rabus, T.; Kaltenhäuser, S. (2024). A review of international best practices in integrating space launch activities with air traffic management: guidance for future space launch in the Singapore region. *Acta Astronautica*, *226*, 728–759. https://doi.org/10.1016/j.actaastro.2024.10.010.

[59] Ghazali, F.E.M.; Rashid, S.A.; Sadullah, A.F.M. (2018). Disparity between the procurement process best practices for PPP projects in the UK and Malaysia. *Proceedings of the Institution of Civil Engineers - Management, Procurement and Law*, *171*, 264–270. https://doi.org/10.1680/jmapl.17.00057.