Sustainable Construction Site Planning and Resource Efficiency

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ABSTRACT

This study examines sustainable construction site planning and resource efficiency, focusing on industry challenges, sustainability principles, and the role of technology and policy in promoting sustainable practices. The objective is to identify best practices, innovative strategies, and frameworks to enhance resource efficiency and waste management in the construction industry, with a particular emphasis on Malaysia. A systematic literature review was conducted, analysing publications from 2018 to 2024 sourced from Science Direct, ResearchGate, and Scopus. Key areas explored include energy efficiency, waste reduction, the use of sustainable materials, and advancements in green technology. Findings reveal that while sustainable construction is essential, it faces significant challenges including lifecycle assessments, adoption of green building technologies, and the integration of sustainable materials. Policy support and industry collaboration are critical to advancing resource efficiency and ensuring long-term sustainability. Specific results indicate that techniques like Design for Disassembly (DfD), Building Information Modeling (BIM), and the 3R approach (Reduce, Reuse, Recycle) significantly improve waste management and resource optimization. The study concludes with actionable recommendations for policymakers, industry professionals, and educators emphasizing the need to adopt sustainable practices and leverage technological innovations to achieve global Sustainable Development Goals (SDGs) while minimizing environmental impacts.

Keywords: Sustainable construction, resource efficiency, construction site planning, waste management, SDGs.

INTRODUCTION

As part of a Sustainable Development Goals (SDGs), all countries, both developed and developing, must acknowledge that reducing poverty and other forms of deprivation must be coordinated with plans to improve health and education, reduce inequality, boost economic growth, combat climate change, and protect the forests and oceans (THE 17 GOALS, n.d.). Therefore, the construction industry which has a significant impact on a variety of aspects of society, the economy, and the environment, are essential contributors to the achievement of SDGs. Besides, the pressing need to address the contribution the construction industry makes to global greenhouse gas (GHG) emissions highlights the significance of developing more sustainable construction practices (Hasselsteen et al., 2024).

There are a few sustainability fundamentals influenced by the SDGs in the construction industry such as shaping collaborative partnerships, adopting green building standards, incorporating sustainable design, highlighting life-cycle assessment, investing in research and innovation, and concentrating on sustainable materials and technologies (Regona et al., 2024). According to Kiwan et al. (2022), it is possible to achieve a green sustainable structure by incorporating water and energy features, innovative building design, passive solar design, employing energy-efficient types of equipment, utilizing sustainable building materials, and constructing a green roof and practical landscaping. Nonetheless, the exploitation, development, and management of resources, coupled with inadequate pollution control, result in numerous environmental issues due to insufficient environmental considerations. On the other hand, if these problems are not addressed strategically, they will further exacerbate and wield challenges in the direction of sustainable construction (Kamar & Hamid, 2011).

Thus, driven by environmental concerns, economic efficiency, and social factors, Malaysia has been actively adopting sustainable practices, with an emphasis on waste management, energy efficiency, emissions reductions, policy frameworks, and stakeholder initiatives on achieving green building standards. The implementation of sustainable construction and green buildings has emerged as a significant concern in Malaysia since the Malaysian Construction Industry Master Plan (2005-2015) (Kamar & Hamid, 2011) which focuses on the relationship between construction, human development, and marginalizing environmental aspects (Abd. Hamid et al., 2012). However, it was observed that the Malaysian construction industry is fall behind in waste management, rainwater harvesting, and reduction of carbon footprint if compared to the developed nations (Kamar & Hamid, 2011).

Research Objective

This research aims to provide a comprehensive understanding of sustainable construction practices and the critical factors that influence their adoption. By examining existing methods, industry challenges, and key sustainability principles, the study will identify areas for improvement and strategic opportunities in resource management and environmental responsibility. Insights into the role of technology as well as the impact of government policies and financial structures, will offer a foundation for proposing targeted strategies to advance sustainable construction. The findings and recommendations are intended to guide policymakers, industry professionals, and educators in adopting more sustainable practices, ultimately fostering a construction industry that contributes positively to global sustainability goals. Specifically, the objectives are:

1) To analyze current sustainable construction site planning and resource efficiency in both developed and developing countries.

2) To identify best practices and innovative strategies for sustainable construction.

3) To propose a framework for improving resource efficiency in Malaysian construction projects.

Scope And Limitations

This study focuses on environmental responsibility and resource efficiency in sustainable construction, examining key principles such as energy efficiency, waste reduction and sustainable materials. It explores the role of technological tools in optimizing resource use and evaluates the influence of government policies, financial frameworks, and industry standards. While the study incorporates case studies and data from both developed and developing regions, particularly Malaysia, several limitations may impact the generalizability of its findings: variable data quality, limited examination of digital technologies and temporal constraints due to evolving practices. Despite these limitations, the study offers valuable insights for advancing sustainability in construction and highlights the need for adaptable, context-specific strategies.

Significance Of Study

This research advances sustainable construction practices by identifying key principles, challenges, and strategies that promote environmental responsibility and resource efficiency. By focusing on Malaysia and similar contexts, the study highlights specific barriers and opportunities faced by construction sectors in diverse regulatory and technological landscapes. It also underscores the importance of innovative solutions such as design for disassembly, Embraced Wood methods, and BIM in enhancing resource management, waste reduction and energy efficiency.

The findings inform policymakers, industry leaders and educators on effective policy frameworks, financial models and educational programs that support sustainable construction. Ultimately, the study aims to guide the industry toward achieving Sustainable Development Goals (SDGs), reducing environmental impacts, and fostering a resilient and sustainable construction sector.

LITERATURE REVIEW

Sustainable construction has become a critical focus globally due to environmental concerns and resource scarcity and according to Kiwan et al. (2022), civil engineering and architectural sectors are the most substantial sectors that integrate sustainable technologies and renewable energy resources in their applications of green structures. In Malaysia, sustainable construction practices have gained momentum as the government and industry stakeholders aim to reduce environmental impacts and enhance resource efficiency. This literature review explores existing studies and reports on sustainable construction site planning and resource efficiency within developed countries and the Malaysian context, focusing on material resource efficiency, waste management, energy efficiency, emissions reduction, policy framework and initiatives, and the challenges faced by the sector.

Material Resource Efficiency and Waste Management

The sustainability sector of the construction industry acknowledges sustainable materials as a primary research focus. This is because the production and utilization of conventional building materials contribute to the degradation of the environment and the depletion of natural resources (Chen et al., 2024). A recent study in developed countries indicates that approximately 30% to 40% of natural resources were utilized by the construction industry (Kamar & Hamid, 2011), as a result, the use of green materials is a necessary component of any sustainable development strategy, rather than an option (Tazmeen & Mir, 2024).

Disposing of agricultural, industrial, and construction waste, as well as other solid wastes, has been identified as a major contemporary issue for both developing and developed countries (Chen et al., 2024). Thus, the construction industries have been promoting the sustainable sourcing, and recycling of materials, and demand an exploration of technology and management's role in mitigating material waste at construction sites (Abkar et al., 2024). Therefore, to lessen waste and greenhouse gas emissions, some construction stakeholders have adopted the Design for Disassembly system, which produces easily recoverable products, parts, and materials from demolished, refurbished, or transformed structures (Mañes-Navarrete et al., 2024).

Besides, increasing recycling rates through improved processing techniques and management practices, such as implementing a comprehensive transportation action plan, could alleviate environmental impact. While, enhancing recycling methods for construction waste, such as concrete, metal, asphalt, and wood, could help reduce the demand for new raw materials. (Munir et al., 2024). For example, brick and glass waste, often encountered during demolition, can be repurposed into pozzolanic materials and glass fiber, respectively; asphalt waste may serve as aggregates for new asphalt layers; plastic waste can be converted into other plastic products or composites; metal waste can be recycled into new metals; timber can be processed into boards; and concrete waste can be transformed into concrete aggregates (Lee et al., 2023).

Munir et al. (2024) studied the environmental impact of construction and demolition waste fine fractions derived from concrete elements throughout their life cycle and found that approximately 50% of the construction and demolition waste is recycled, 20% is used as fill material and only 30% of the waste is sent to landfill. Other studies by Abdullah (2024) which evaluates the sustainability of a business proposal to create eco-blocks by using construction and demolition waste and ash from municipal solid waste found that the remanufactured eco-blocks constructed using concrete blocks standard, save around 50% of construction cost. As an additional point of interest, a sustainability index of 0.874 was achieved by taking into account several different parameters such as a reduction in carbon dioxide emissions, eco-cost savings, re-manufacturing costs, concrete savings, profit, and energy savings. Moreover, it reduced the need for new sand and gravel, while also providing improved mechanical properties for various construction applications.

Circular construction, especially through design for disassembly philosophy approaches, is essential for reducing waste and carbon emissions. Thus, Mañes-Navarrete et al. (2024) in their research, adopted the philosophy of timber structures as the timber's modularity and renewability fit well with the design for disassembly principles. They found that, by prioritizing adaptability in design, architects and engineers can help create structures that improve occupant social well-being and promote long-term sustainability. Asa et al. (2024) introduce a workflow using Embraced Wood methods for non-destructively analyzing and arranging reclaimed timber into beams of any span. Using computational design and robotic fabrication with natural fibers, it addresses irregularities and contamination in timber, allowing more waste wood to be reused structurally in construction rather than being burned.

Material waste mitigation strategies are vital in improving construction performance while achieving the Sustainable Development Goals. A few key practices such as the 3R approach (Reduce, Reuse, Recycle), Industrial Building Systems (IBS), Building Information Modeling (BIM), and Material Management Adoption (MMA) that play crucial roles in this improvement (Abkar et al., 2024). Therefore, Construction personnel are encouraged to integrate these strategies into their material management practices to further enhance site productivity and efficiency. Chen et al. (2024) investigated and analyzed sustainable construction materials derived from waste materials and discovered that while the materials perform well technically, they require improvement in environmental, economic, and social sustainability aspects.

Furthermore, most sustainable construction materials are still in the experimental stage, necessitating additional research into issues such as human toxicity, long-term savings, and maintenance costs (Chen et al., 2024). In Malaysia, where construction waste cycling is regulated by agencies such as the Department of Environment Malaysia, the Solid Waste and Public Cleansing Management Corporation, as well as the National Solid Waste Management Department (Lee et al., 2023), these sustainability challenges are particularly relevant. Each agency plays a distinct role in ensuring that construction waste recycling aligns with environmental standards and sustainability goals, supporting Malaysia’s efforts to adopt sustainable waste management practices in construction.

Energy Efficiency and Emissions Reduction

Around half of the world's carbon dioxide (CO_2) emissions come from building operations, and the construction industry happens to be an enormous waste producer and a major consumer of non-renewable resources. A recent study indicates that, in developed countries including Malaysia, housing construction uses 30% of energy, while 50% of energy is used for heating and cooling inside the buildings (Kamar & Hamid, 2011). Thus, in 2011, Malaysia pledged to reduce its CO_2 emissions by up to 40% from the 2005 emission level, a commitment made as part of the nation’s broader sustainability and environmental conservation efforts (Kamar & Hamid, 2011).

Munir et al. (2024) investigate methods for reducing emissions and energy consumption to produce greener construction and demolition waste fine fractions concrete components by focusing on the importance of sustainable energy for material pre-treatment and efficient transportation strategies such as route planning and vehicle selection. While Asa et al. (2024) stated that, the Embraced Method in timber applications reduces carbon emissions by simplifying fabrication and using unprocessed materials. The integration of clay and fiber in the bio-composite structure provides natural fire safety and moisture control, lowering the need for additional materials and treatments. This approach not only reduces emissions compared to traditional engineered timber but also allows for greater design flexibility, which can help reduce resource consumption and emissions in future high-density construction (Asa et al., 2024).

The steel sector is a major contributor to global greenhouse gas emissions, posing challenges for climate change efforts due to its high energy demands and dependence on carbon-intensive processes. Therefore, Hishan et al. (2024) study the feasibility of reducing emissions in Malaysia’s steel sector, aiming for net-zero emissions by 2050. However, The International Energy Agency highlights that decarbonizing the steel sector is complex, given its need for high heat, reliance on carbon inputs, and structural barriers such as low profit margins and long asset lifespans. Thus, The Technological Innovation Systems (TIS) framework offers a pathway by identifying critical actors, institutions, and processes essential for advancing low-carbon technologies in the Malaysian steel industry.

Concrete shell structures provide an efficient building floor system that reduces environmental impacts by lowering material usage and carbon emissions. Oval et al. (2023) research showcases a large-scale concrete shell floor system supported by columns, tie rods, and a leveled floor, with prefabricated segments that allow for easy transport, assembly, and potential disassembly to support a circular construction economy. Their study details the structural design, automated fabrication using a reconfigurable mold and robotic concrete spraying, as well as the assembly and disassembly process on-site. Life-cycle analysis reveals that this prototype reduces embodied carbon by about 50% compared to traditional flat slabs, with further potential for optimization (Oval et al., 2023).

Enhancing energy efficiency and reducing emissions are crucial for establishing a more sustainable, economical, and healthful built environment. The construction industry can significantly contribute to mitigating climate challenges, enhancing community well-being, and ensuring a sustainable future through these practices. Malaysia's strategy to achieve this target involves a combination of initiatives, including promoting renewable energy sources, enhancing energy efficiency across various sectors, and implementing sustainable practices within industries, particularly the construction sector, which is a major contributor to CO_2 emissions (Shahril, 2024). This objective was established in line with international climate initiatives that seek to reduce emissions of greenhouse gases to slow the rate of climate change.

Policy Framework and Initiatives

The construction industry is increasingly under pressure to adopt sustainable practices due to its substantial impact on the environmental, social, and economic dimensions of sustainability. To address these challenges, various policy frameworks and initiatives have been developed globally, with countries implementing strategic measures aimed at promoting resource efficiency, reducing carbon emissions, and minimizing waste within the construction sector. In Malaysia, a comprehensive policy framework and several initiatives have been established to promote sustainable construction site planning and resource efficiency. Key components include the National Construction Policy 2030, the Construction 4.0 Strategic Plan, Green Building Initiatives, the Zero Energy Building Facilitation Programme, Green Practices Guidelines for the construction sector, as well as Environmental, Social, and Governance integration. Additionally, the Construction Industry Development Board Malaysia (CIDB) is responsible for the development and improvement of Malaysia's construction industry. Additionally, the CIDB takes proactive measures to address the issue of sustainable construction and facilitate the implementation of this concept among stakeholders (Kamar & Hamid, 2011).

Various initiatives have been implemented globally to emphasize sustainable construction, driving the development of policy frameworks aimed at reducing the environmental impact of the construction sector. For example, design for disassembly promotes adaptability and waste reduction by allowing building components to be easily rearranged and reused, aligning with the global sustainability goals outlined in the United Nations Environment Programme's 2021 Global Status Report for Buildings and Construction (UNEP, 2021).

Regona et al. (2024) discuss the outcomes of the Rio United Nations Summit in 2013, which introduced 17 SDGs with 169 targets. These goals are structured around the pillars of social, environmental, and economic sustainability, emphasizing human needs, environmental stewardship, human rights, and global partnerships. Their findings highlight specific SDGs with significant potential to advance sustainability within the construction industry, particularly those focusing on affordable and clean energy, industry innovation and infrastructure, and the development of sustainable cities and communities. In Malaysia, policy measures, including the National Construction Policy, Green Building Index, and Construction 4.0 Strategic Plan, reflect similar commitments to sustainability by fostering resource efficiency, energy reduction, and green building standards within the industry (Xu et al., 2024).

Cortés et al. (2023) and Zadeh Kazemi et al. (2023) study the role of sustainability reporting in the construction industry, highlighting its impact on achieving SDGs. Cortés et al. (2023) discuss the construction sector's substantial effects on the environment, society, and economic growth, noting increasing societal expectations

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for companies to adopt sustainability reporting to manage their sustainability impacts. However, sustainability reporting remains less examined in construction compared to other sectors, with companies primarily motivated by instrumental or strategic factors tied to social and political considerations, rather than by normative drivers like moral responsibility or stewardship.

Similarly, Zadeh Kazemi et al. (2023) identify sustainability reporting as a crucial yet underutilized tool for advancing sustainability in construction. Their review reveals significant knowledge gaps and calls for a broader theoretical framework to address the complex nature of sustainability reporting. They propose an assessment and lifecycle approach by categorize sustainability reporting research into four theme which are assessment and indicators, determinants, strategic management, as well as outcomes. This framework demonstrates that sustainability reporting has strong potential to support the construction industry's progress toward SDGs by enhancing transparency, accountability, and sustainability performance.

Alsehaimi et al. (2024) examine Building Information Modeling (BIM) as a transformative technology in the construction, logistics, and supply chain management sectors. Their study employs a Partial Least Squares (PLS) equation modeling approach to assess how BIM adoption affects key sustainability metrics. The findings indicate that integrating BIM with sustainable practices enhances collaboration, streamlines design processes, reduces waste, and improves energy efficiency. These insights offer valuable information for academics, industry practitioners, and policymakers working to advance sustainable practices within the construction sector.

Likewise, Waqar et al. (2023) investigate BIM's role in promoting sustainability in smaller-scale construction projects, with a focus on resource efficiency, energy performance, waste reduction, and collaborative decision-making. Through a literature review, Exploratory Factor Analysis (EFA), and Structural Equation Modeling (SEM) with a case study in Perak, Malaysia, the study identifies positive correlations between BIM adoption and benefits such as design optimization, energy efficiency analysis, material selection, life cycle assessment, and waste reduction. This research underscores BIM's essential role in supporting environmentally responsible practices and achieving sustainable outcomes in small-scale green building projects.

Jamil and Fathi (2016) explore the combined implementation of Sustainable Construction (SC) and Lean Construction (LC) as a strategic approach to reduce waste, yielding both environmental and economic benefits. Despite the potential advantages, many construction organizations face challenges in effectively integrating these practices. Poor implementation and lack of cohesion between SC and LC are common in several countries, highlighting the need for improved strategies. Sustainable Lean Construction (SLC) emerges as an effective method to bridge SC and LC, emphasizing waste elimination and enhancing project schedules and costs, thereby strengthening the integration of sustainability within lean construction practices.

Hasselsteen et al. (2024) underscores that collaboration among stakeholders and policymakers is essential to drive significant progress in minimizing the environmental impact of the construction sector. They also mention that the role of regulatory initiatives, technological advancements, and standardized methods for conducting life cycle assessments and data collection as crucial opportunities for sustainability. Ertz et al. (2024) on the other hand, examine the potential of the metaverse to enhance sustainability in the construction industry. Their content analysis highlights that metaverse technology can foster energy efficiency, optimize material and human resources, reduce construction waste, and minimize the environmental impact of buildings. Additionally, the metaverse facilitates improved collaboration and communication among stakeholders, contributing to sustainable construction practices.

METHODOLOGY

The study follows the principles of systematic literature review applied to the field of sustainability and industry, specifically focusing on identifying, retrieving, and selecting relevant publications. A comprehensive literature review serves as the foundation of this study, examining existing research on sustainable construction, including energy efficiency, waste reduction, sustainable materials, and technological advancements like BIM. The review includes journal papers, research papers, articles, conference papers, and websites as open resources. There was no geographical limitation for these studies, but only publications from

2018 to 2024 were considered, and only English-language publications were included. Keywords used were "Sustainable," "Sustainability," "Construction," "Construction Site Planning," and "Resource Efficiency" to locate relevant papers. The documentary research was conducted in databases such as Science Direct, ResearchGate, Emerald, and Scopus. A total of 56 references were extracted across these datasets, and 27 were included in this literature review. Each publication was read in-depth for content analysis and data gathering on sustainable construction site planning and resource efficiency.

RESULTS

The results highlight key aspects of sustainable construction site planning and resource efficiency, explicitly addressing the research objectives:

1. Material Resource Efficiency and Waste Management

Studies show that sustainable construction materials, particularly recycled and reusable ones, significantly reduce environmental impact. Techniques such as Design for Disassembly (DfD) and Embraced Wood methods enhance material reuse, while the 3R approach (Reduce, Reuse, Recycle), Building Information Modeling (BIM), and Industrialized Building Systems (IBS) effectively minimize construction waste, especially in Malaysia. These findings validate the second research objective by identifying innovative strategies for sustainable construction.

2. Energy Efficiency and Emissions Reduction

Green building technologies, renewable energy integration, and low-carbon materials help reduce the construction sector's carbon footprint. For instance, Malaysia's goal of reducing CO_2 emissions by 40% from 2005 levels has driven research into sustainable practices, like concrete shell structures and bio-composite materials, which cut embodied carbon emissions by up to 50% compared to traditional methods. This directly supports the first objective by analyzing current practices in developed and developing countries.

3. Policy Frameworks and Initiatives

Strong regulatory support and industry collaboration are crucial for advancing sustainability. While BIM improves waste reduction, supply chain efficiency, and lifecycle management, challenges like high implementation costs, limited skilled workforce, and slow policy adoption persist. Emerging technologies, such as Artificial Intelligence (AI) and the Metaverse, present opportunities for optimizing resource efficiency and digital construction planning. These insights align with the third objective by proposing a framework for improving resource efficiency in Malaysian construction projects.

Overall, while Malaysia has made progress, barriers such as high costs, regulatory gaps, and low adoption rates of green materials remain. Future efforts should focus on scaling up sustainable materials, enhancing digital construction tools, and improving policy implementation to align with global sustainability goals. Table 1 shows the Summary of Key Findings in Sustainable Construction.

Table 1: Summary of Key Findings in Sustainable Construction

No.	Location	Year	Sustainable construction area	Aim	Finding	Ref.
1		2024	Material Resource Efficiency and Waste Management	To conduct a thorough review of sustainable construction materials produced from waste materials	The findings indicate that while most Sustainable Construction Materials (SCMs) exhibit strong engineering performance, there is a need for improvements in showcasing their	Chen et al. (2024)

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					environmental (33.3%), economic (40%), and social sustainability (73.3%).	
2.		2024	Policy Framework and Initiative	To investigate the role of Metaverse in promoting sustainability within the construction industry.	The analysis of the content indicates that metaverse technology advances sustainable construction practices by cultivating energy conservation, optimizing the use of materials and workforce, minimizing construction waste and the ecological footprint of buildings, and improve cooperation and communication among stakeholders, ultimately leading to more sustainable construction results.	Ertz et al. (2024)
3.		2024	Material Resource Efficiency and Waste Management Energy Efficiency and Emissions Reduction	To analyze the role of environmentally friendly materials in advancing sustainable building practices.	Green materials are fundamental, not merely optional, elements of any sustainable development strategy.	Tazmeen & Mir (2024)
4.	Malaysia	2024	Material Resource Efficiency and Waste Management	To evaluate the influence of the 3R principles (Reduce, Reuse, Recycle), Modern Methods of Architecture (MMA), Building Information Modeling (BIM), and Industrialized Building Systems (IBS), on improving Construction Site Performance within the Malaysian construction sector	The adoption of the 3R strategy, BIM, IBS, and streamlined material management practices is essential for minimizing material waste on Malaysian construction sites. This integration supports significant waste minimization, enhanced construction productivity, optimized resource allocation, and whole project achievement.	Abkar et al. (2024)
5.		2024	Material Resource Efficiency and Waste Management Energy Efficiency and Emissions Reduction	To review present literature on timber structures designed in accordance with the Design for Disassembly (DfD) standard, focusing on their principles,	Embracing circular construction principles, particularly Design for Disassembly and Adaptability (DfD/A), is vital for minimizing waste and carbon emissions in the construction sector.	Mañes-Navarrete et al. (2024)

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				benefits, and practical applications, while advocating for the broader acceptance of DfD timber systems to intensify sustainability and circularity in the construction industry.	Timber construction, with its inherent modularity and renewable properties, provides a viable pathway toward achieving circularity in building design. By prioritizing adaptable designs, architects and engineers can develop structures that enhance occupant well-being and foster long-term environmental sustainability.	
6.		2024	Material Resource Efficiency and Waste Management Energy Efficiency and Emissions Reductio	To investigate innovative approaches and critical stages in the utilization of fine fractions from Construction and Demolition Waste (CDW) for concrete component production	The study indicates that approximately 30% of CDW is disposed of in landfills, 50% is recycled, and 20% is repurposed as fill material. This underscores the opportunity to increase recycling rates through enhanced processing and management practices. Furthermore, it highlights the importance of integrating sustainable energy sources in pretreatment processes and optimizing transportation strategies, such as efficient route planning and vehicle selection, to produce more environmentally friendly building materials from CDW fine fractions.	Munir et al. (2024)
7.		2024	Policy Framework and Initiative	To investigate how BIM can facilitate sustainability and enhance logistics and supply chain management	The findings demonstrate that various factors, such as lifecycle management, material tracking and traceability, supplier collaboration, supply chain efficiency, transportation, waste minimization, and recycling processes, play a critical role in the adoption of BIM. Integrating BIM with sustainable practices has been shown to improve collaboration, optimize design workflows, minimize	Alsehaimi et al. (2024)

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					waste generation, and enhance energy efficiency.	
8.		2024	Material Resource Efficiency and Waste Management	To assess the sustainability of a proposed business model that focuses on re-manufacturing concrete substantial from CDW and ash generated from municipal solid waste combustion, with the aim of producing eco-blocks for use in construction applications.	Remanufactured eco-blocks provide multiple benefits compared to conventional concrete blocks, including a manufacturing cost nearly 50% less, substantial environmental and resource conservation through reduced demand for new sand and gravel, and improved mechanical performance.	Abdullah (2024)
9.		2024	Material Resource Efficiency and Waste Management Energy Efficiency and Emissions Reduction	To propose a workflow for the non-destructive analysis of reclaimed timber elements, encompassing the computational arrangement of irregular timber pieces into beams of any span. This process includes the robotic fabrication of laminated timber beams reinforced with natural fibers, aiming to maximize resource efficiency and promote sustainable construction practices.	Embraced Wood introduces techniques to mitigate material inconsistencies and contamination, which are key barriers to the structural reuse of timber. This strategy enables a greater volume of waste wood to be reintegrated into construction projects, reducing the need for disposal or incineration.	Asa et al. (2024)
10.	Malaysia	2024	Energy Efficiency and Emissions Reduction	To investigate the feasibility of decarbonizing Malaysia's steel sector to achieve net-zero emissions by 2050.	This study offers a preliminary investigation into the perspective, concentrating on identifying the drivers within Technological Innovation Systems that can facilitate and expedite the transition towards steel decarbonization.	Hishan et al. (2024)
11.	Malaysia	2024	Policy Framework and Initiative	To deliver a comprehensive	The findings underscore the opportunities arising	Hasselsteen et al. (2024)

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				review that provides critical insights into emerging research trends and offers strategic guidance for advancing sustainable resource management in construction processes,	from regulatory measures, technological innovations, and the adoption of standardized approaches to life cycle assessments (LCAs) and data collection. The study highlights the critical role of collaboration among stakeholders and policymakers in achieving meaningful reductions in the construction sector's environmental footprint. This integrated approach, enriched by insights from interviews, provides actionable recommendations that deepen our understanding of sustainable construction practices.	
12.		2024	Policy Framework and Initiative	To analyze how Artificial Intelligence (AI) can be effectively implemented across the key phases of a project such as planning, design, construction, and operation and maintenance.	The findings identify Sustainable Development Goals (SDGs) relevant to the construction industry, highlighting that SDGs 7 (Affordable and Clean Energy), 9 (Industry, Innovation, and Infrastructure), and 11 (Sustainable Cities and Communities) offer the greatest potential to advance sustainability in construction.	Regona et al. (2024)
13.		2024	Energy Efficiency and Emissions Reductio Policy Framework and Initiative	To propose a solution for reducing construction waste in the Architecture, Construction, and Engineering industry through the development of a disassemblable brick partition wall, enabling easier reuse and recycling of materials to promote sustainable building practices.	The analysis underscores the adaptability and flexibility of the proposed system, which can be tailored to different sizes and configurations. Additionally, the system delivers substantial advantages in construction speed and energy efficiency, both throughout the structure's operational lifespan and during its future reuse or repurposing phases.	Xu et al. (2024)

14.		2023	Policy Framework and Initiative	To provide an overview of the current state of literature on Sustainability Reporting (SR) within the construction industry.	The literature suggests that sustainability disclosure is largely driven by instrumental or socio-political motivations, with notable disparities in the content and quality of reports influenced by various factors. To maximize the benefits of such reporting, it should be aligned with corporate strategy, supported by tailored management practices to ensure its effectiveness.	Cortés et al. (2023)
15.		2023	Policy Framework and Initiative	To examine SR within the construction industry, focusing on its role in promoting transparency and accountability, and emphasizing its significance in advancing the achievement of SDGs.	The review identifies substantial knowledge gaps and methodological constraints, stressing the importance of adopting a broader theoretical framework to better understand the complexities of SR. It highlights four central themes for research: evaluation and indicators, influencing factors, strategic management, and the impacts of SR.	Zadeh Kazemi et al. (2023)
16.		2023	Energy Efficiency and Emissions Reductio	To present the conceptual and structural design of an innovative construction system, emphasizing the automation of fabrication through the use of an actuated, reconfigurable, and reusable mould combined with a robotic concrete spraying process	This prototype achieves a reduction in cradle-to-gate embodied carbon of approximately 50% compared to conventional flat slabs, even prior to further refinements and optimizations.	Oval et al. (2023)
17.	Malaysia	2023	Material Resource Efficiency and Waste Management Energy Efficiency and	To investigate the role of BIM in promoting sustainability within smaller-scale construction	The findings reveal significant positive correlations between the adoption of BIM and several key factors, such as early-stage design optimization, energy	Waqar et al. (2023)

			Emissions Reduction Policy Framework and Initiative	projects,	performance analysis, material selection, life cycle assessment, waste minimization, and the use of prefabrication techniques.	
18.	Malaysia	2023	Material Resource Efficiency and Waste Management	To collect and analyze information on the types of construction waste most frequently recycled, as well as the recycling methods employed, to better understand current practices and identify opportunities for improving waste management and resource recovery in the construction industry.	The study reveals that paper and cardboard waste are predominantly recycled into new paper products, while asphalt waste can be reused as aggregates in the production of new asphalt layers. Demolition waste such as bricks and glass can be repurposed into pozzolanic materials and glass fibers, respectively. Metal waste is recyclable into new metal products, and plastic waste can be converted into various plastic items or composites. Additionally, timber waste can be processed into boards, and concrete waste can be repurposed as aggregates for new concrete applications.	Lee et al. (2023)
19.		2016	Policy Framework and Initiative	To establish a foundation for future empirical research by examining the various dimensions of Supply Chain (SC) and Life Cycle (LC) processes.	Future research seeks to examine the opportunities and challenges associated with expanding the proposed model by integrating Building Information Modeling (BIM) and the IBS as fundamental tools for developing a conceptual framework that promotes lean and sustainable integration. A simplified version of the model could act as a benchmark for driving lean and sustainable improvements, informed by input from industry experts, project practitioners, owners, and stakeholders. The model illustrates how strategic	Jamil and Fathi (2016)

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					implementation can enable the seamless integration of LC and Supply Chain (SC) principles, from the design stage through to project completion, providing a systematic pathway to achieve LC and SC alignment.	
20.	Malaysia	2011	Material Resource Efficiency and Waste Management Energy Efficiency and Emissions Reduction Policy Framework and Initiatives	To showcase the ongoing initiatives by the government and private sectors in Malaysia aimed at fostering sustainable development practices and advancing the construction of green buildings.	The barriers to adoption include a shortage of skills and capacity, overlapping responsibilities among government agencies, sluggish industry uptake of government initiatives, inadequate investment in research and innovation, and an imbalanced cost-benefit ratio associated with implementing green technologies.	Kamar & Hamid (2011)

DISCUSSION

Overview Of Sustainable Construction Site Planning and Resource Efficiency

The construction industry plays a pivital role in achieving Sustainable Development Goals (SDGs) due to its extensive social, economic, and environmental impacts (THE 17 GOALS, n.d.; Hasselsteen et al., 2024). Sustainable practices, supported by policies promoting resource efficiency and technological innovations, are essential for fostering economic growth, reducing inequality, and protecting natural resources (Hasselsteen et al., 2024). In Malaysia, initiatives such as the Malaysian Construction Industry Master Plan aim to improve waste management, energy efficiency, and emissions reduction. However, challenges such as limited waste management progress and carbon footprint reduction persist compared to developed countries (Kamar & Hamid, 2011; Abd. Hamid et al., 2012).

Challenges And Barriers Face in Implementing Sustainable Construction Site Planning and Resource Efficiency

The implementation of sustainable construction practices faces several challenges and barriers across various contexts, particularly in developing regions. Some key obstacles include high costs, project delays, limited availability of green materials, a lack of knowledge, and insufficient environmental legislation (Saleh & Alalouch, 2015). Similarly, Malaysia faces issues such as limited skills and capacity, overlapping governmental roles, and slow industry uptake of government sustainability initiatives or efforts to encourage sustainable construction such as the Green Technology Strategy and Green PASS programs (Abd. Hamid et al., 2012). There is also a need for stronger research and innovation in green technologies, as well as for a clearer cost-benefit understanding of these technologies (Kamar & Hamid, 2011; Abd. Hamid et al., 2012).

Moreover, Design for Disassembly and adaptability in construction are further hindered by the labour-intensive nature of these processes, regulatory hurdles, and a limited market for salvaged materials. Standardization and testing protocols are insufficiently developed, and adaptable design guidelines are needed to accommodate regional variations (Mañes-Navarrete et al., 2024). In industrialized construction, high initial capital and transportation costs impede the growth of systems like the Industrialized Building System (IBS) in Malaysia, where adoption rates remain below 3% (Al-Aidrous et al., 2023). Digitalization, though recognized as valuable, also encounters significant organizational cost barriers (Musarat et al., 2024).

Another major hurdle is the adoption of digital technologies and Building Information Modeling (BIM). While BIM can enhance lifecycle management, material tracking, waste reduction, and recycling, its adoption is limited by complexities in supply chain optimization, dealer engagement, and transportation costs (Alsehaimi et al., 2024). Additionally, awareness and understanding of Life Cycle Cost Analysis (LCCA), an essential tool for assessing economic sustainability, remain low among construction personnel, with only 4.4% of employees showing high awareness (Altaf et al., 2022). Additionally, the application of AI to support sustainability in construction remains under-researched, with limited practical insights into its potential to improve project sustainability and align with SDGs (Regona et al., 2024).

CONCLUSION

In conclusion, accelerating the adoption of sustainable construction site planning and resource efficiency is crucial for achieving Sustainable Development Goals (SDGs) and minimizing environmental impact. Key recommendations include establishing green public procurement, promoting Research and Development (R&D) in sustainable construction practices, and implementing public education initiatives to shift perceptions toward sustainable building (Kamar & Hamid, 2011). Adopting lifecycle costing, encouraging the Industrialized Building System (IBS) approach, and providing legislative and financial frameworks will support green building adoption and resource efficiency.

Furthermore, integrating artificial intelligence (AI) into construction can optimize design processes and enhance energy efficiency. AI's ability to analyze large datasets and simulate various scenarios empowers architects and engineers to make informed decisions aligned with green building standards (Regona et al., 2024). To fully harness AI's potential, interdisciplinary collaboration is needed, focusing on R&D to address technical and workforce challenges and data privacy concerns. Comprehensive policies and empirical studies can provide insights into the benefits of AI in sustainable construction, allowing the industry to progress toward a sustainable, efficient future and significantly contribute to global sustainability objectives (Regona et al., 2024).

REFERENCES

1. Abd. Hamid, Z., Che Ali, M., Mohd. Zain, M. Z., Khairolden, M., Abdul Rahim, A. H., Dzulkalnine, N., Mohd. Noor, Mohd. S., Mat Kilau, N., & Ambon, F. (2012). *Towards a sustainable and green construction in Malaysia*. Malaysian Construction Research Journal. https://www.researchgate.net/publication/274989726
2. Abdullah, Z. T. (2024). Remanufacturing construction and demolition waste and incineration ashes into eco-blocks: Quantitative sustainability assessment. *Results in Engineering, 103242*. https://doi.org/10.1016/j.rineng.2024.103242
3. Abkar, M. M. A., 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*(7), e28721. https://doi.org/10.1016/j.heliyon.2024.e28721
4. Al-Aidrous, A. M. H., Shafiq, N., Rahmawati, Y., Mohammed, B. S., Al-Ashmori, Y. Y., Baarimah, A. O., & Alawag, A. M. (2023). Major blocking factors affecting the application of industrialized building system. *Ain Shams Engineering Journal, 14*, 102151. https://doi.org/10.1016/j.asej.2023.102151
5. Alsehaimi, A., Waqar, A., Alrasheed, K. A., Bageis, A. S., Almujibah, H., Benjeddou, O., & Khan, A. M. (2024). Building a sustainable future: BIM's role in construction, logistics, and supply chain management. *Ain Shams Engineering Journal*. https://doi.org/10.1016/j.asej.2024.103103
6. Altaf, M., Alalaoul, W. S., Musarat, M. A., Hussain, A., Saad, S., Rabbani, M. B. A., & Ammad, S. (2022). Evaluating the awareness and implementation level of LCCA in the construction industry of Malaysia. *Ain Shams Engineering Journal, 13*(5), 101686. https://doi.org/10.1016/j.asej.2021.101686

7. Asa, P., Feghali, C. E., Steixner, C., Tahouni, Y., Wagner, H. J., Knippers, J., & Menges, A. (2024). Embraced Wood: Circular construction method for composite long-span beams from unprocessed reclaimed timber, fibers and clay. *Construction and Building Materials, 416*, 135096. https://doi.org/10.1016/j.conbuildmat.2024.135096
8. Chen, L., Yang, M., Chen, Z., Xie, Z., Huang, L., Osman, A. I., Farghali, M., Sandanayake, M., Liu, E., Ahn, Y. H., Ala'a H. Al-Muhtaseb, Rooney, D. W., & Yap, P.-S. (2024). Conversion of waste into sustainable construction materials: A review of recent developments and prospects. *Materials Today Sustainability*. https://doi.org/10.1016/j.mtsust.2024.100930
9. Cortés, D., Traxler, A. A., & Greiling, D. (2023). Sustainability reporting in the construction industry – Status quo and directions of future research. *Heliyon, 9*, e21682. https://doi.org/10.1016/j.heliyon.2023.e21682
10. Ertz, M., Ouerghemmi, C., & Njika, Y. N. (2024). Impact of the metaverse on sustainability in the construction industry. *Sustainable Futures, 8*, 100335. https://doi.org/10.1016/j.sftr.2024.100335
11. Hasselsteen, L., Lindhard, S. M., & Kanafani, K. (2024). Resource management at modern construction sites: Bridging the gap between scientific knowledge and industry practice and needs. *Journal of Environmental Management, 366*, 121835. https://doi.org/10.1016/j.jenvman.2024.121835
12. Jamil, A. H. A., & Fathi, M. S. (2016). The integration of Lean Construction and Sustainable Construction: A stakeholder perspective in analysing sustainable lean construction strategies in Malaysia. *Procedia Computer Science, 100*, 634–643. https://doi.org/10.1016/j.procs.2016.09.205
13. Kamar, K. A. M., & Hamid, Z. A. (2011). Sustainable construction and green building: The case of Malaysia. *WIT Transactions on Ecology and The Environment*. https://www.witpress.com/Secure/elibrary/papers/ST11/ST11002FU1.pdf
14. Kiwan, S. M., Alhassan, M. A., & Hamad, B. M. (2022). Development of a simple sustainable camping shelter for addressing the needs of refugees in Jordan. *Results in Engineering, 14*, 100404. https://doi.org/10.1016/j.rineng.2022.100404
15. Lee, J. C., Thedy, W. H., Ng, J. L., & Lee, S. (2023). Recycled waste of construction industry in Malaysia: A review. *IOP Conference Series Earth and Environmental Science, 1205*(1), 012030. https://doi.org/10.1088/1755-1315/1205/1/012030
16. Mañes-Navarrete, D., Redón-Santafé, M., & Paya-Zaforteza, I. (2024). Timber structures designed for disassembly: A cornerstone for sustainability in 21st century construction. *Journal of Building Engineering, 96*, 110619. https://doi.org/10.1016/j.jobe.2024.110619
17. Munir, Q., Lahtela, V., Kärki, T., & Koivula, A. (2024). Assessing life cycle sustainability: A comprehensive review of concrete produced from construction waste fine fractions. *Journal of Environmental Management, 366*, 121734. https://doi.org/10.1016/j.jenvman.2024.121734
18. Musarat, M. A., Alaloul, W. S., Zainuddin, S. M. B., 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
19. Regona, M., Yigitcanlar, T., Hon, C., & Teo, M. (2024). Artificial Intelligence and Sustainable Development Goals: Systematic Literature Review of the construction industry. *Sustainable Cities and Society, 108*, 105499. https://doi.org/10.1016/j.scs.2024.105499
20. Saleh, M. S., & Alalouch, C. (2015). Towards sustainable construction in Oman: Challenges & opportunities. *Procedia Engineering, 118*, 177–184. https://doi.org/10.1016/j.proeng.2015.08.416
21. Shahril, M. (2024, January 31). National Energy Transition Roadmap (NETR): Charting a path to a sustainable energy landscape - MIDA | Malaysian Investment Development Authority. *MIDA | Malaysian Investment Development Authority*. https://www.mida.gov.my/national-energy-transition-roadmap-netr-charting-a-path-to-a-sustainable-energy-landscape/
22. Tazmeen, T., & Mir, F. Q. (2024). Sustainability through materials: A review of green options in construction. *Results in Surfaces and Interfaces*. https://doi.org/10.1016/j.rsurfi.2024.100206
23. THE 17 GOALS. (n.d.). *United Nations*. https://sdgs.un.org/goals
24. UNEP. (2021). *Global status report for buildings and construction*. United Nations Environment Programme (UNEP). https://www.unep.org/resources/report/2021-global-status-report-buildings-and-construction

25. Waqar, A., Othman, I., Saad, N., Azab, M., & Khan, A. M. (2023). BIM in green building: Enhancing sustainability in the small construction project. *Cleaner Environmental Systems, 11*, 100149. https://doi.org/10.1016/j.cesys.2023.100149
26. Xu, Y., Liu, S., & Heisel, F. (2024). Towards sustainable construction waste management: Study on a disassemblable brick partition wall for the architecture, construction, and engineering industry. *Circular Economy, 3*(1), 100078. https://doi.org/10.1016/j.cec.2024.100078
27. Zadeh Kazemi, M. Z., Elamer, A. A., Theodosopoulos, G., & Saleh F.A. Khatib. (2023). Reinvigorating research on sustainability reporting in the construction industry: A systematic review and future research agenda. *Journal of Business Research, 167*, 114–145. https://doi.org/10.1016/j.jbusres.2023.114145