Challenges in Sustaining Net Zero Buildings in Malaysia

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ABSTRACT

Malaysia aims to achieve net zero greenhouse gas (GHG) emissions by 2050. The insufficient awareness and comprehension of the net-zero building idea among the Malaysian populace has impeded the construction sector from realising its potential advantages. According to the Global Carbon Project data, Malaysia recorded 7.63 tonnes of carbon emissions per capita. This country also lacks adequate training and expertise in the installation of innovative technologies for net-zero energy buildings. The objective of this study is to investigate the challenges related to the maintenance of net zero buildings in Malaysia. This study uses a questionnaire as a research instrument for data collection. The poll received replies from 104 civil engineers. It conducted a descriptive analysis of the obtained data, assessing the mean and frequency of respondents' agreement. The results indicate that Malaysia's workforce has the lowest average score of 2.13, signifying a deficiency in knowledge concerning the skills necessary for sustainable construction practices. In contrast, the highest mean of 4.43 indicates a positive agreement about the effective integration of Malaysia's current technology into net-zero construction projects. To attain the 2050 net zero objective, stakeholders in Malaysia, including government, industry, and the public, must enhance their understanding of net zero sustainability, promote the adoption of sustainable buildings to achieve net zero, and collectively assume responsibility for environmental conservation.

Keywords: Greenhouse Gas Emissions, Net Zero Building, Sustainability, Challenges, Construction Industry

INTRODUCTION

According to Akmal (2017), the construction business is vital for bolstering the national economy and elevating the living standards of Malaysians by advancing socioeconomic infrastructure and buildings. A Malaysian organisation called the Construction Industry Development Board (CIDB) says that the construction industry supports around 196 other businesses and makes up 15% of all manufacturing output (CIDB, 2021). Lin Chen et al. (2023) indicate that the building industry accounts for 36% of global energy consumption and 39% of global carbon dioxide emissions. It is a major consumer of non-renewable energy and a considerable emitter of greenhouse gases. Müller et al. (2013) contend that construction is a fundamental sector and activity that substantially contributes to carbon emissions.

During the 26th United Nations Climate Change Conference (COP26) in Glasgow in 2021, nations underscored the imperative of decreasing carbon dioxide emissions by 45% by 2030 to achieve net zero by mid-century (United Nations, 2023). This corresponds with the objectives of the Paris Agreement, which seeks to restrict global warming to much below 2°C, with endeavours to remain under 1.5°C. In response, more than 1,000 colleges from 68 nations pledged to attain net-zero emissions by 2050 and to alter their environmental effect. Furthermore, over 5,200 enterprises committed to achieving net-zero carbon objectives by 2050, indicating a substantial global initiative to diminish greenhouse gas emissions (Jennifer, 2023).

Various challenges hinder the realisation of net-zero buildings in Malaysia. The significant upfront costs associated with net-zero energy buildings may discourage many companies (Karlsson et al., 2021). The integration of energy-efficient technologies, renewable energy systems, and high-performance materials can considerably increase construction costs (Uspenskaia, et al. 2021). Apprehensions over the potential costs of net

zero-energy buildings often lead companies to forgo investigating and achieving the possibility of net zero emissions (Lou & Hsieh 2024). The Malaysian construction industry lacks sufficient installation training and comprehension of new technology for net zero energy buildings (Prasad, D et al., 2024).

LITERATURE REVIEW

The construction industry is pursuing net-zero carbon emissions within a limited timeframe, motivated by increasing apprehensions regarding climate change and obligations established in the 2015 Paris Agreement (Sylvia, 2022). The construction sector significantly contributes to global carbon emissions, representing around 40% of total emissions worldwide, highlighting the critical necessity for sustainable practices (Global Alliance for Buildings and Building, 2019). The Malaysian construction sector aims to attain a net-zero energy and carbon-built environment by 2050, in accordance with international initiatives (CIDB, 2021). Achieving net-zero emissions is a formidable undertaking that requires significant modifications across multiple economic sectors, such as energy, transportation, and construction materials (Sovacool et al., 2020). The revisions will mandate the integration of renewable energy technology, improvements in energy efficiency, and the use of circular economy principles in buildings to reduce waste and emissions (Kibert, 2016). Achieving net zero necessitates collaboration among policymakers, industry stakeholders, and researchers to devise creative solutions and establish comprehensive regulatory frameworks (UNEP, 2021). Moreover, it is essential to identify the barriers within the construction industry in this country that hinder the attainment of net-zero buildings. The literature assessment reveals many problems in sustaining net zero structures. Here's a list of the challenges:

Technological and Infrastructure

Using modern green technology, like smart building solutions and efficient renewable energy systems, can be hard because it costs a lot to get started and needs special infrastructure. Insufficient technical preparedness may obstruct the extensive use of net-zero building attributes.

The government has been advocating for digital transformation within the construction sector and urging the use of digital technology initiatives. Building information modelling (BIM) and industrialised building systems (IBS) are two technologies endorsed by governments in recent decades. However, local industries have not widely adopted BIM as expected. This mostly results from a deficiency in motivation for change (Roaf, S., & Bros-Williamson, J. (2023).

The primary obstacles to digitalisation in the Malaysian construction sector include a preference for established technology, a lack of experienced personnel, initial capital expenditures, and the necessity to validate return on investment (Musarat et al., 2024). These obstacles present a significant hurdle to the implementation of renewable energy systems, as the Malaysian construction sector contends with inadequate infrastructure and essential utilities. The lack of dependable infrastructure complicates the integration of intermittent renewable energy into the grid (Cantarero, 2020). Construction firms must prioritise addressing barriers to digital transformation. Businesses that postpone technology adoption run the risk of falling behind more agile competitors. The adoption of construction technologies can significantly enhance production and efficiency within the sector (Musarat et al., 2024).

Financial Constraints

Net Zero-Energy building projects offer substantial energy savings; nevertheless, their initial expensive outlay may dissuade developers and investors (Ana et al., 2018). The higher costs of eco-friendly building materials significantly raise the overall expenses of sustainable construction, making these projects pricier than conventional designs (Kibert, 2016). The high initial costs of renewable technologies like energy storage systems, wind turbines, and solar panels, along with the lack of financial support, continue to make it hard for Net Zero-Energy building principles to become widely used (Olubunmi et al., 2016). Developers and clients sometimes express concern regarding the profitability of these investments due to the extended timescale for returns.

Consumers prioritise a business's immediate profitability over its commitment to environmental sustainability; hence, they question the widespread adoption of net zero-energy buildig efforts (Kibert, 2016). This issue is

particularly pronounced in Malaysia, where financial resources are limited, and the lack of subsidies or tax incentives exacerbates the challenge (Ismail et al., 2023; Cantarero, 2020). The volatility of energy prices is a further economic challenge, as it diminishes the actual savings generated by Net Zero-Energy building programs. These alterations impede accurate assessments of the cost-effectiveness of these initiatives, thereby discouraging investment (Mustaffa et al., 2022; Ana et al., 2018; Oh, T. H. et al., 2018).

Furthermore, energy invoices may demonstrate a deficiency in transparency or fail to accurately reflect the true expenses of energy consumption. When energy costs appear relatively low compared to other expenses, individuals may be less inclined to explore energy-efficient methods or adopt sustainable building practices (Olubunmi et al., 2016).

Lack of Skilled Workforce

The construction sector has a deficiency in knowledge and expertise, resulting in erratic technician performance (Mustaffa et al., 2022 & Ana et al., 2018). A multitude of green technologies are intricate and require specialised knowledge for their implementation. The absence of skilled or technical personnel will diminish stakeholders' and customers' confidence in the application of green technology (Ilmi et al., 2024). Employees possessing adequate specialised skills might serve as a crucial cost-reduction solution for Net Zero Energy buildings. They must adhere to specific policies and standards to employ sustainable practices in construction projects (Ana et al., 2018).

The association of builders and contractors claims that the construction industry needs an additional 650,000 workers under normal circumstances to satisfy labour demand. A lack of competent labour in construction results in project delays, quality control problems, and heightened financial risks for the contractor. Insufficient design and implementation experience may result in elevated expenses. Inaccurate life cycle cost analysis may result in unforeseen economic consequences for a building. The on-site work demonstrates inadequacies, does not conform to standards, or is of inferior quality. Increased direct costs will arise from demolition, garbage disposal, and project modifications; any delays will incur additional indirect expenses (Mustaffa et al., 2022 & Ana et al., 2018).

Moreover, the Malaysian government is deficient in training programs, knowledge dissemination, and technology transfer activities for the advancement of green and sustainable buildings (Cantarero, 2020). Certain companies abstain from sending employees for training in soft skills and current green building expertise. This stems from the apprehension that, after training, individuals may depart for more profitable roles at competing firms, leading to talent attrition and a squandering of time and money. As a result, unskilled personnel will lack the capability to handle and manage sophisticated new technology (Ilmi et al., 2024).).

Public Awareness and Education

The insufficient awareness and comprehension among the public, developers, and legislators concerning the advantages and viability of net-zero buildings may hinder their progress. Abidin (2010) identified poor awareness as the second most significant obstacle. This suggests that respondents may lack comprehensive awareness of the support and incentives offered by their local government for investing in sustainable buildings.

In addition, the lack of information and awareness among top management impairs construction businesses' readiness to use green practices in projects. Despite their awareness of environmental concerns, their understanding of sustainable development is inadequate (Wright, 2012). Moreover, many individuals exhibit a notable weakness in their individual environmental awareness, which may be linked to Malaysia's educational shortcomings regarding the understanding of net-zero building. Numerous folks often lack comprehension of the true importance of sustainability as a worldwide concept and of energy efficiency. As a result, individuals lack comprehension of the Net Zero-Energy buildings project (Ana et al., 2018).

Due to a lack of comprehensive understanding of net-zero buildings, individuals may perceive these technologies or systems as ineffective and challenging to monitor, potentially leading to misinterpretation of associated information (Ana et al., 2018). Furthermore, the concept of net-zero is both innovative and complex, making its execution difficult without construction stakeholders who possess significant experience and sufficient

competence in relevant fields. This could lead to a disregard for the benefits of sustainable development (Dahle & Neumayer , 2001).

Government Issues

Thorough laws and regulations are essential for facilitating the adoption of renewable energy and achieving net-zero emissions. Many African countries require extensive legislation, strong legal frameworks, and financial incentives to encourage investment in sustainable energy projects (Cantarero, 2020). Net-zero buildings possess intricate supply chains involving several stakeholders and varying interests influenced by regulatory frameworks. The government's demonstration of energy-efficient methods is essential for advocating energy-saving constructions (Lindkvist et al., 2014).

Malaysian policy is advancing towards the objectives of net zero-energy buildings; yet, misconceptions persist. The implementation of Net Zero-Energy buildings is restricted to new constructions. No conclusive designs or requirements exist for the Net Zero-Energy buildings upgrade (NorthPass, 2012). Currently, it is evident that policies lack coherence. The principal challenge is the integration of the EPDB and other EU directives into national legislation. In certain instances, varying national and urban planning restrictions hinder the execution of optimal energy strategies or postpone the realization of cost effectiveness due to legal requirements (Ana et al., 2018).

Furthermore, the government should be a principal advocate for the promotion and execution of green buildings. The government may provide financial and non-financial incentives, regulations, and policies to promote the advancement of green buildings (Qian, J., Siriwardana, C., & Shahzad, W.2024). The Malaysian government exhibits negligible concern for this issue and does not offer financial assistance or incentives to foster the green building sector, thereby hindering the implementation of green building technology (Ohene et al,. 2022). Government incentives are essential for corporations to innovate or adopt new technologies and processes. Construction firms will be reluctant to engage in sustainable development without support or incentives for energy-efficient initiatives. Small and medium-sized firms are deficient in financing, incentives, and resources, hindering the implementation of sustainable development (Ilmi et al., 2024).

Lack of Information and Supply Chain

This results from the nascent stage of green building technology and the construction industry's current inability to integrate it into projects. A lack of understanding of the essential functions and costs related to the technology would result in the construction industry adopting unsafe practices in the execution of green building methods (Ayarkwa et al, 2022). Moreover, inadequate product performance poses challenges for architects and labourers. An inferior completed product will adversely impact a company's reputation, thereby diminishing potential earnings. Consequently, developers and stakeholders will exhibit reluctance to engage in green construction initiatives (Chan et al,. 2017).

Moreover, the absence of recognized precedents constrains the support accessible to developers in the design of sustainable buildings. Regulations are essential for all individuals in positions of leadership. Stakeholders and clients will be concerned about potential concealed risks associated with this new construction process if they do not receive sufficient guidance. Estimating the requisite equipment and materials is unfeasible, perhaps leading to increased waste (Ilmi et al., 2024).

METHODOLOGY

This survey received a total of 104 completed questionnaires, comprising 83 online submissions and 21 physical forms from civil engineers. The questionnaire comprises close-ended questions formulated using a Likert scale, divided into two sections: Section A assesses the respondents' history, while Section B identifies the the challenges faced by Malaysia in sustaining net-zero construction. This study's data was analyzed using Excel to obtain descriptive statistics (means and rankings).

RESULT

Guided by a comprehensive literature assessment, this research outlines six primary issues related to the

attainment of net-zero buildings in Malaysia. Twenty-one questions were formulated to elicit respondents' views on diverse issues, including technological and infrastructure challenges, financial limitations, a shortage of skilled labour, insufficient public awareness and education, governmental obstacles, and inadequacies in information and supply chain management. Participants assessed each challenge using a five-point Likert scale, from "strongly disagree" (1) to "strongly agree" (5). The subsequent outcomes of this survey are presented.

Technological and Infrastructure

Respondents offered their views on the technological and physical capabilities necessary for progressing net-zero building initiatives in Malaysia, emphasizing critical perspectives on the current infrastructure, innovation, and resource availability needed to support these improvements. The majority were favorable; however, few expressed concerns regarding the physical infrastructure constraints. Figure 1 shows average score of 4.43, respondents overwhelmingly agree that current technologies in Malaysia can effectively integrate into net-zero building initiatives, securing the top position. This indicates that respondents possess confidence in the adequacy and appropriateness of current technology for executing net-zero activities, demonstrating optimism about the nation's technological preparedness. Malaysia has committed to achieving net-zero greenhouse gas emissions by 2050.

Perceptions of infrastructural deficiencies impeding advancements in sustainable building methods received a second-place ranking with an average score of 4.32. The elevated score signifies that respondents harbor significant apprehensions about inadequacies in current infrastructure that may hinder the advancement of sustainable construction initiatives. Infrastructure influences the development of net zero projects via several supply and demand-side mechanisms. For instance, investments in infrastructure related to electricity, telecommunications, and transportation are significant (Mousavi, S.,2023). Despite confidence in technology capabilities, the perceived inadequacy of the accompanying infrastructure highlights critical areas for enhancement.

The perspective that certain technological solutions are inadequately employed in achieving the net zero objective came in third, with an average score of 3.96. This indicates a moderate to high level of agreement regarding the underutilization of current technologies in meeting net zero objectives. Underutilization may stem from a deficiency of awareness, resources, or competence, indicating the necessity to more effectively leverage and integrate current technological solutions. With an average score of 3.95 on the adequacy of its current infrastructure to facilitate net-zero building initiatives, Malaysia secured a fourth-place ranking. Although the score indicates generally positive perceptions, it is the lowest among the assessed factors. This suggests that while many respondents perceive the infrastructure as sufficient, a significant proportion feels it requires improvement. Infrastructure must robustly support net zero building initiatives to ensure the successful execution of these projects.

The analysis concludes that Malaysia possesses strong technological capabilities for net-zero construction projects, although it also reveals significant issues around infrastructure deficiencies and the underutilization of some technologies. Resolving these infrastructure challenges and enhancing the use of technological solutions can significantly advance sustainable and net-zero building practices in Malaysia.

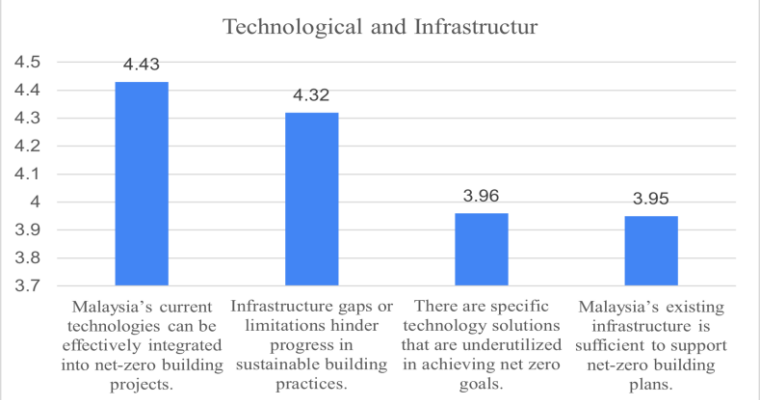

Figure 1: Result of Technology and Infrastructure

Financial Constraints

Figure 2 Analysis of the data provided on the financial constraints of sustainable construction projects shows that respondents demonstrated a strong belief in the significant long-term return on investment (ROI) associated with net-zero construction practices in Malaysia, with an average score of 3.86. This demonstrates confidence in the financial viability of adopting sustainable approaches in construction projects, which could be driven by factors such as improved energy efficiency and operating cost savings over time.

Second, respondents' overall acceptance of the costs associated with implementing sustainable and net-zero technologies was good, with an average score of 3.84. This demonstrates the positive outlook for investment in sustainable practices, although the initial financial outlay may be affected by environmental impact and regulatory compliance considerations.

However, respondents also acknowledged challenges in obtaining financial support for sustainable construction projects, with an average score of 3.31. This highlights the recognition of barriers such as accessing finance or seeking financial incentives, underscoring the importance of addressing barriers to financing in promoting sustainable development in the construction industry.

Additionally, while respondents generally agreed (mean = 3.24) there are challenges to maintaining the cost of net-zero buildings. This highlights the need for continued investment and innovation to overcome barriers and ensure the long-term viability of net zero building practices.

In conclusion, the analysis highlights the perceived opportunities and challenges related to the financial aspects of sustainable construction projects. Despite confidence in the potential economic benefits and overall cost acceptance, addressing barriers to financing and sustaining net-zero buildings remains important to drive widespread adoption of sustainable practices in the construction industry.

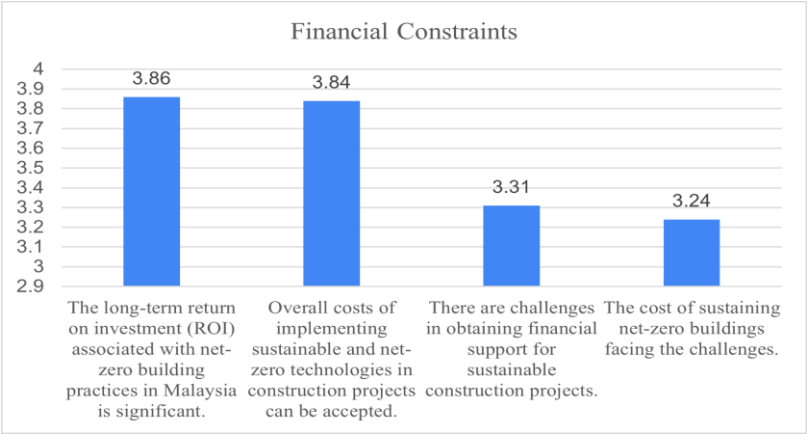

Figure 2: Result of Financial Constraints

Lack of Skilled Workforce

The results shown in Figure 3 highlight both advantageous and problematic elements of skill development in Malaysia's net zero construction technologies. A modest confidence level (mean = 3.48) in comprehending the requisite skills indicates that industry professionals have a fundamental understanding of the competencies needed for sustainable construction. This knowledge does not inherently equate to experience or preparedness to tackle the intricacies of sustainable building projects, which require interdisciplinary skills and innovative methodologies (Lützkendorf & Lorenz, 2011).

The reported low score (mean = 2.19) for access to training opportunities indicates a significant issue. In the absence of sufficient training programs, a substantial segment of the workforce may be ill-equipped to facilitate the shift toward sustainable construction techniques. Research highlights that capacity-building programs are essential for providing professionals with the technical expertise and practical skills necessary for the implementation of energy-efficient technologies (Zuo et al., 2012). Furthermore, the absence of accessible

training may intensify the current skills gap, obstructing Malaysia's capacity to attain its sustainability objectives.

The poor confidence level in staff's comprehension of abilities for sustainable practices (mean = 2.13) indicates an urgent necessity for educational initiatives. Research demonstrates that insufficient awareness of green building principles and technologies frequently correlates with resistance to implementing sustainable practices (Darko et al., 2017). This underscores the need for focused awareness initiatives and collaborations between industry and academia to cultivate a better-informed workforce.

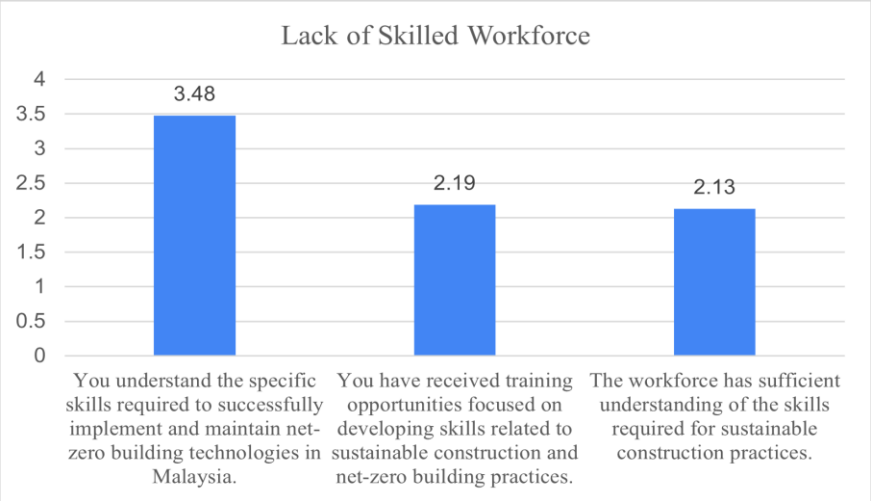

Figure 3: Result of Lack of Skilled Workforce

Public Awareness and Education

The results illustrated in Figure 4 highlight the crucial importance of public awareness in promoting the adoption of sustainable construction practices. A robust consensus among respondents (mean = 3.83) about the role of public perception underscores that favorable attitudes toward sustainability can substantially affect decisions throughout all stages of the construction process. This coincides with research highlighting that public knowledge generates demand for environmentally friendly practices, compelling politicians and industry stakeholders to prioritize sustainability (Darko et al., 2017).

Although educational initiatives aim to enhance public comprehension of sustainable construction, the modest score of 2.88 suggests constraints in its breadth, accessibility, or efficacy. According to research, tailoring educational programs to specific cultural and regional contexts can boost their effectiveness (Umar et al., 2020). In Malaysia, obstacles like inequitable resource allocation, inadequate funding, and the absence of comprehensive frameworks may impede the efficacy of these programs. Robust educational initiatives are crucial for fostering public comprehension of the alignment between sustainability, national agendas, and global commitments, including the Paris Agreement (Fallah et al., 2022).

The average score of 2.21 for public comprehension of net-zero building principles highlights a significant knowledge deficiency. Net-zero buildings, which equilibrate energy use with renewable energy production, embody a sophisticated notion necessitating both technical comprehension and societal endorsement (Zuo et al., 2012). The Malaysian public's insufficient awareness may hinder the adoption of these practices, as comprehension is essential for fostering trust and acceptance of new technology. Studies indicate that educational initiatives focused on certain sustainability principles, along with effective communication tactics, can markedly enhance public comprehension and endorsement (Zhang et al., 2018).

In conclusion, while we acknowledge the importance of public awareness and have undertaken certain initiatives to educate the Malaysian populace about sustainable building methods, we still need to further enhance understanding, especially when it comes to complex concepts such as net-zero buildings.

Improved educational initiatives and communication techniques are essential for fostering greater awareness and support for sustainable construction practices in Malaysia.

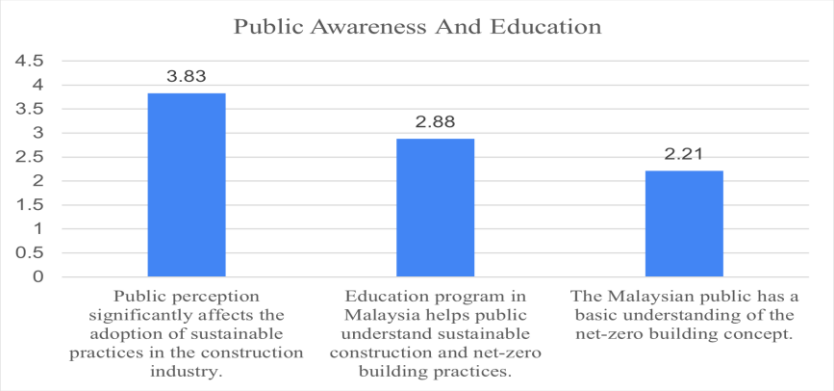

Figure 4: Result of Public Awareness and Education

Government Issues

The average number of responses was 3.10. Most of the people who answered agreed that Malaysia's government rules on net-zero and sustainable building were clear and complete. Figure 5 illustrates this. This indicates the presence of a basic regulatory framework, yet significant potential for improvement remains. Comprehensive and detailed rules are crucial for aligning sector practices with national sustainability goals and international commitments, such as the Paris Agreement (UNFCCC, 2015). Research demonstrates that ambiguous or inadequate regulations might hinder investment and obstruct the transition to sustainable practices (Zhang et al., 2018).

A mean score of 3.05 for policy stability signifies a modest degree of satisfaction with the consistency of governmental policies. Regulatory stability and predictability are essential for fostering long-term investment and enabling effective planning for sustainable construction projects (Gillingham & Bollinger, 2017). Frequent regulatory changes or unclear implementation timelines might obstruct industry efforts to adopt sustainable practices. In Malaysia, ensuring policy coherence between federal and state levels is crucial for the comprehensive implementation of net-zero building principles. Participants expressed moderate satisfaction (mean = 3.00) with government-sponsored financial aid programs. Globally, researchers recognize financial incentives—including grants, tax rebates, and low-interest loans—as useful tools for encouraging the adoption of sustainable construction practices (Zuo et al., 2012). Even though Malaysia has made progress in offering incentives, the relatively low score suggests that these systems may not be targeted or strong enough to meet the needs of the industry. To make financial strategies work better, research shows how important it is to make them open to everyone, fair, and in line with industry standards (Darko et al., 2017).

The poor satisfaction level (mean = 2.70) with the efficacy of permission and approval processes for net-zero building projects underscores a substantial issue. Although legal frameworks are in place, inefficiencies in approval processes can obstruct project implementation, increase costs, and discourage acceptance. Studies show that better processes, aided by digital technologies and knowledgeable regulatory staff, can greatly boost the speed at which projects are approved (Shi et al., 2016).

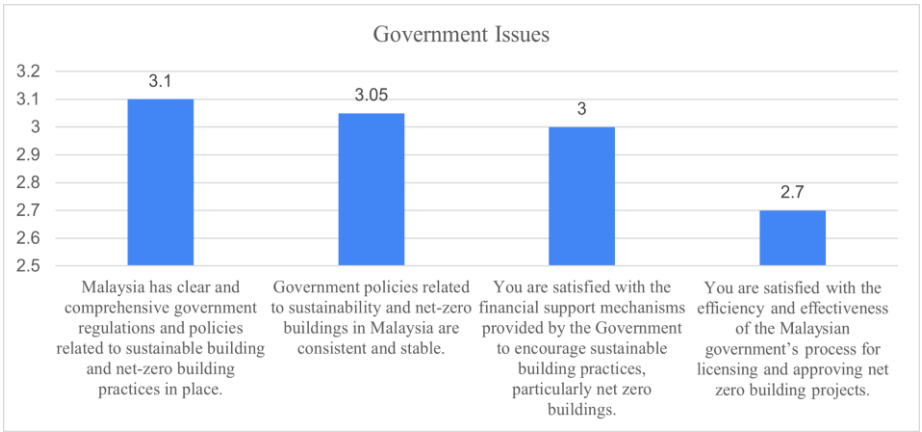

Figure 5: Result of Government Issues

Lack of Information and Supply Chain

Analyzing data on knowledge deficiencies and supply chain challenges in sustainable construction projects may reveal the respondents' difficulties. Initially, respondents expressed moderate agreement (mean = 2.85) with the difficulty of obtaining current, credible information on sustainable construction. This indicates that obtaining credible information is challenging, potentially hindering informed decision-making and sustainable construction methods. These challenges may require the enhancement of information transmission methods or the centralization of resources to provide construction industry stakeholders with precise, timely information. Participants expressed concerns regarding supply chain transparency affecting sustainable component sourcing, with a score of 2.78. This shows how hard it is to find and check the authenticity of sustainable products and materials throughout the supply chain. This makes it harder for project developers to build with sustainable materials. Transparency and accountability in the supply chain can mitigate these problems and enhance confidence in sustainable component procurement. Respondents exhibited moderate satisfaction (mean = 2.59) about communication throughout the net-zero construction supply chain. We can enhance the efficacy of communication. Enhanced communication and collaboration among supply chain stakeholders can facilitate the success of net-zero construction projects.

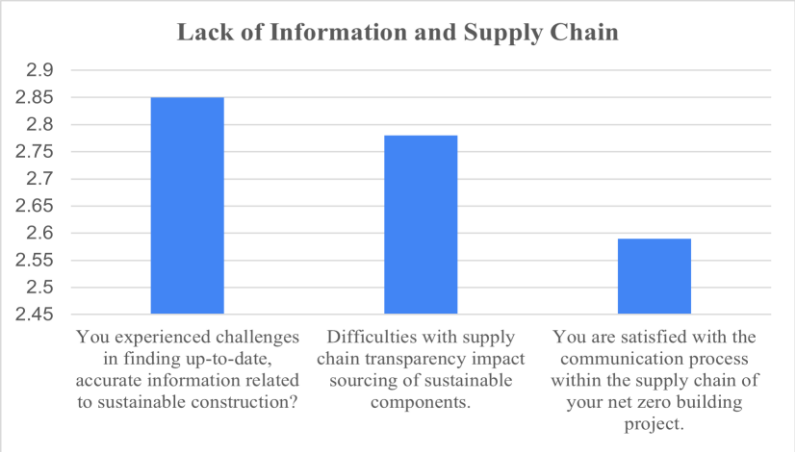

Figure 6: Result of Lack of information and Supply Chain

CONCLUSION

Ensuring net-zero buildings in Malaysia involves a complex array of challenges that require a thorough and coordinated approach. Significant hurdles include the high initial costs of green technology, the lack of comprehensive technical expertise, and the limited knowledge among stakeholders about the long-term benefits of net-zero buildings. Furthermore, Malaysia's hot and humid climate poses unique design and operational challenges for achieving energy efficiency and incorporating renewable energy.

Mitigating these challenges necessitates substantial governmental backing through policies, incentives, and regulatory frameworks that promote net zero principles. Collaboration among policymakers, the corporate sector, and academics is essential for fostering innovation, improving capacity, and developing contextually relevant solutions. Moreover, increasing public knowledge of the economic and environmental benefits of net zero buildings can drive demand and facilitate wider adoption.

Ultimately, achieving and sustaining net zero buildings in Malaysia relies on persistent commitment, targeted investments, and a unified strategy for environmental sustainability. By overcoming these challenges, Malaysia may position itself as a leader in sustainable construction in Southeast Asia, significantly contributing to global climate action goals.

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