



INDICATORS, CHALLENGES AND STRATEGIES IN IMPLEMENTING NET-ZERO CARBON CONSTRUCTION PROJECTS

Azliza Abdullah¹, Liyana Mohamed Yusof², Rahimi A. Rahman³

*^{1,2,3}Faculty of Civil Engineering Technology,
UNIVERSITI MALAYSIA PAHANG AL-SULTAN ABDULLAH*
*³Faculty of Graduate Studies,
DAFFODIL INTERNATIONAL UNIVERSITY*

Abstract

The global construction industry, responsible for over 10% of worldwide greenhouse gas emissions, particularly in carbon dioxide (CO₂) from energy use, contributes a substantial 38% to global emissions. Unchecked emissions pose a serious risk of hastening climate change impacts. To secure a habitable future, collective responsibility is incumbent upon all construction stakeholders to mitigate the carbon footprint. The prospect of a more sustainable environment lies in proactive emission reduction and the pursuit of net-zero carbon construction. This study investigates the indicators, challenges, and strategies in implementing net-zero carbon construction projects. Employing an explorative qualitative approach, twenty project managers and environmental officers were interviewed, and thematic analysis identified management, project attributes, and technology as crucial indicators. Despite increased global awareness, the implementation of net-zero carbon in construction faces significant challenges, including financial constraints, governance issues, management, lack of competency, and limited access to green technologies. Effective strategies necessitate incorporation of governance, knowledge, management, and technology elements. Ultimately, this study enhances understanding of the construction industry by delineating indicators, challenges, and strategies in achieving net-zero carbon construction.

Keywords: Net-Zero Carbon, Construction, Indicators, Challenges, Strategies

² Senior lecturer. Email: liyanam@umpisa.edu.my

INTRODUCTION

The construction industry, encompassing the development and construction of various infrastructure, residential, and commercial projects, carries a significant burden in terms of greenhouse gas emissions. These emissions include gases such as carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O), which contribute to the greenhouse effect and subsequent climate change. The construction industry's activities, ranging from material production to on-site operations, result in a notable share of global emissions. Carbon dioxide emissions resulting from the consumption of energy play a crucial role in climate change. When analysing the construction industry's impact specifically in terms of CO₂ emissions from energy usage, it becomes apparent that the industry is a significant contributor. The processes involved in constructing buildings, manufacturing construction materials, and operating construction machinery require substantial energy inputs. As a result, the construction industry alone contributes an alarming 38% to the total global CO₂ emissions (United Nations Environment Programme, 2020).

If greenhouse gas emissions from the construction industry and other sectors are not effectively controlled and reduced, there is an increased likelihood of exacerbating the adverse effects of climate change (Chen *et al.*, 2023). Climate change manifests in numerous ways, including rising global temperatures, sea-level rise, more frequent and severe extreme weather events, disruptions to ecosystems, and negative impacts on human societies and economies. By not addressing and curbing greenhouse gas emissions, the construction industry runs the risk of amplifying these detrimental effects and compromising the well-being of the planet and its inhabitants. Therefore, achieving net-zero carbon is crucial for addressing environmental problems and reducing greenhouse gas emissions. To achieve net-zero carbon, there are three strategies: avoiding, reducing, and removing CO₂ emissions (Mengis *et al.*, 2022). This involves reducing the carbon footprint of the building materials, as well as the energy used during construction, operation, and eventual demolition.

By actively working to decrease emissions, the construction industry can contribute to mitigating climate change and its associated impacts. This involves adopting cleaner and more efficient technologies, implementing sustainable practices throughout the construction process, and reducing reliance on fossil fuels. Reducing the use of carbon emissions in construction activities is a crucial step toward achieving a more sustainable environment for both present and future generations. Several studies have proposed measures to reduce carbon emissions in the construction industry, such as reducing the use of concrete and rebar in construction projects (Kim *et al.*, 2020), promoting awareness of the sources of carbon footprint in the construction industry (Sizirici *et al.*, 2021), and proposing energy savings and emission reductions in a targeted manner (Chen *et al.*, 2022). By minimising emissions resulting from construction activities, such

as energy consumption, transportation, and waste management, the industry can significantly reduce its carbon footprint and environmental impact. The development of low-carbon building materials, such as interlocking compressed earth bricks, has also been proposed as a way to reduce carbon emissions in the construction industry (Asman *et al.*, 2020).

The construction industry can contribute to creating a more sustainable environment. Such efforts can help mitigate the impacts of climate change and provide a better world for present and future generations, fostering a harmonious balance between human development and environmental stewardship. This highlights the urgent need for emission management and reduction to mitigate the risks associated with climate change. Achieving net-zero carbon in construction requires a holistic approach that involves collaboration between architects, engineers, contractors, and building owners to ensure that all aspects of the project work together to achieve the goal of net-zero carbon emissions. Consequently, this study aims to identify the indicators, challenges and strategies in the implementation of a net-zero carbon construction project. To achieve this objective, semi-structured interviews were conducted with twenty industry respondents, and thematic analysis was used to interpret the results from the interviews. The study results could help to identify the indicators and thus assist in developing suitable strategies to avoid, reduce, and remove CO₂ emissions in construction projects.

LITERATURE REVIEW

The concept of net-zero carbon in construction involves achieving carbon neutrality throughout a building's life cycle, including the construction, operation, and embodied energy stages. This goal is accomplished by minimizing energy consumption, using renewable energy sources, and offsetting remaining emissions (Chen *et al.*, 2023). This includes considering carbon emissions from energy consumption during the manufacturing of construction materials and construction process. The goal of net-zero carbon extends beyond sectors that are already advanced in reducing emissions and focus on "harder-to-treat" sectors such as buildings (Fankhauser *et al.*, 2021). Previous studies have shown that construction activities contribute significantly to global energy consumption and carbon dioxide emissions, making it crucial to reduce carbon emissions in the construction industry (Chen *et al.*, 2023). One of the strategies proposed by Jankovic *et al.* (2021) includes a fabric-first approach, focusing on building envelope design and considering alternative building materials such as biochar, bioplastic, agricultural waste, animal wool, fly ash, and self-healing concrete can also help to reduce carbon emissions. It is also notable that controlling the carbon emission through monitoring and efficient planning by monitoring operational hours at construction sites can reduce the operational energy. The UKGBC Net Zero Carbon Buildings Framework provides guidance for achieving net-zero

carbon in operational energy and construction emissions (Cohen *et al.*, 2021). The use of energy-efficient technologies can also play a crucial role in reducing initial costs and increasing energy efficiency (Mishchenko *et al.*, 2018) (Ling *et al.*, 2019). However, transitioning to net-zero carbon cities requires systemic transformation and strategic sequencing of mitigation actions (Seto *et al.*, 2021). The development of effective carbon policies is essential to ensure that decreasing emissions is a legal necessity and that all construction companies use emissions control measures to meet carbon standards and regulations (Mustaffa *et al.*, 2022). By understanding the current practice and implementation of these strategies, the construction industry can significantly reduce its carbon emissions and contribute to mitigating climate change.

Based on the literature review, there are several knowledge gaps in research related to net-zero carbon in construction practice. Lack of policies and guidelines for net-zero energy buildings in hot and humid climates, particularly in developing countries highlighted the need for further study of specific strategies and standards to achieve net-zero carbon in these regions (Feng *et al.*, 2019). Limited research can be found on effective strategies and technologies for achieving net-zero carbon in "harder-to-treat" sectors such as buildings and construction compared to more advanced sectors such as manufacturing (Fankhauser *et al.*, 2021). The scarcity of lifecycle-based studies on the environmental effects of net-zero energy buildings calls for more research that considers the life cycle impacts of such buildings, including embodied carbon and other environmental factors (Thiel *et al.*, 2013). Additionally, it applies to the construction industry as the need to control and reduce carbon emissions must start from the design, manufacturing of construction materials, construction process, technology and operational stage of the building. The most important issue to highlight pertaining to the knowledge gap in this topic is, most of the studies were done by taking into consideration throughout the design, manufacturing and operational stage of the building instead of during the construction stage (Jankovic *et al.*, 2021). However, it has been evident that construction activities on site have been one of the significant contributors to carbon emission. Although there are studies that has been done for carbon management, it has been found that there is a lack of direct work specifically on net-zero carbon in construction. Therefore, this study aims to address these knowledge gaps through further research that will enhance the understanding of net-zero carbon in construction during the construction stage.

RESEARCH METHODOLOGY

Research Design

Research methodology refers to the systematic plan or framework that researchers follow to conduct their research and achieve their research objectives. It involves selecting appropriate research methods, data collection techniques, and data analysis procedures to address the research questions or hypotheses (Lindhult and Axelsson, 2021). The choice of research methodology design depends on the nature of the research problem, the research objectives, and the available resources. This study adopted semi-structured interviews to gather data and analyse using thematic analysis. The data from this study were derived from twenty interviews, which all respondents involved in construction management and also environmental officers to gain their insight on the implementation of net-zero carbon in construction practice. The next approach was to analyse with thematic analysis to gain a deep understanding of the research topic and reach qualitative conclusions based on the perspectives and experiences of the respondents.

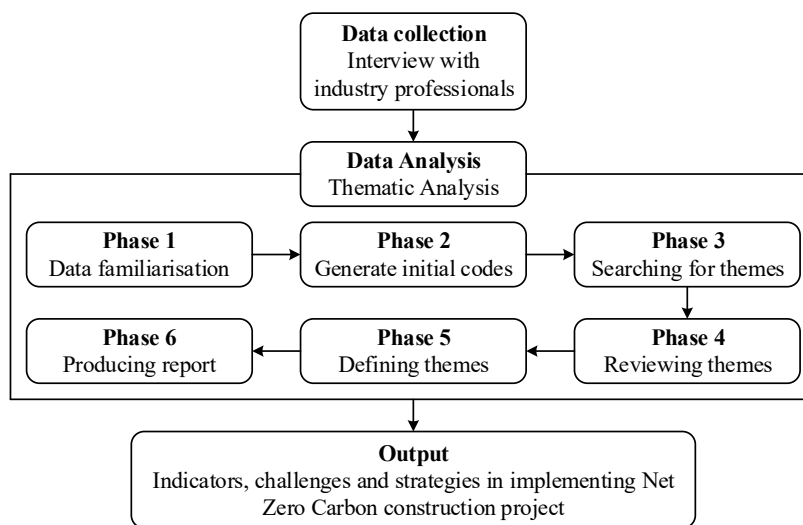


Figure 1: Overview of the Research Methodology

Data Collection

Semi-structured interviews with construction industry professionals were conducted for data collection, aiming to comprehend current carbon management practices on construction sites. Three open-ended questions were asked: 1) What are the indicators in determining the implementation of a net-zero carbon construction project? 2) What are the challenges in implementing a net-zero carbon construction project? and 3) What are the strategies to implement a net-

zero carbon construction project? Follow-up questions were included for diverse responses and in-depth understanding (Zamani *et al.* 2023; Anathan *et al.* 2023). Virtual platforms facilitated interviews, later summarised and validated by respondents. Twenty carefully selected project managers and environmental officers participated between Q4 2022 and Q1 2023 to ensure varied perspectives. The concept of data saturation in theory-based interview studies suggest two key factors: the initial analysis sample size and the stopping criterion (Francis *et al.*, 2010; Radzi *et al.* 2024). From the interview data collected, the subthemes were evaluated regularly, defined and polished. The themes were then tested if it worked with the coded extracts and the complete data set, and reviewed data to look for additional themes. This process leads to a conclusion that data saturation has been achieved. Respondent profiles, chosen based on professional backgrounds in construction site management and environmental monitoring, were identified via LinkedIn. Rigorous criteria ensured relevance. Connection requests with research goals were sent post-identification. This targeted approach not only ensured a pertinent sample but also swiftly engaged participants. New respondents were acquired through networking with initial participants.

Table 1: Respondent Profile

No	Gender	Position	Background	Years of Experience
R1	Female	Assistant Manager	Client	11
R2	Male	Project Manager	Contractor	20
R3	Male	Project Manager	Contractor	30
R4	Male	Project Engineer	Contractor	22
R5	Male	Engineer	Client	20
R6	Male	Project Manager	Contractor	22
R7	Male	Head of Quality Management	Client	17
R8	Male	Resident Engineer	Contractor	20
R9	Male	Engineer	Client	22
R10	Male	Project Manager	Contractor	22
R11	Female	Environmental Executive	Consultant	4
R12	Female	Environmental Officer	Contractor	2
R13	Female	Environmental Officer	Contractor	2
R14	Female	Environmental Officer	Contractor	2
R15	Male	Environmental Officer	Consultant	5
R16	Female	Professional Environmental Engineer	Consultant	20
R17	Male	Health and Safety Manager	Client	23
R18	Female	Health and Safety Executive	Consultant	4
R19	Male	Senior Executive (Safety and Sustainability)	Client	18
R20	Female	Environmental Officer	Contractor	4

Data Analysis

Thematic analysis is a commonly used approach in qualitative data analysis studies in the field of construction management (Saufi *et al.* 2023; Bunjaridh *et al.* 2023). It involves identifying, analysing, and reporting themes or patterns within the data. Thematic analysis was conducted based on the steps recommended by Braun and Clarke (2006). The first step is to get familiar with the data obtained from interviews. Then, initial codes were generated to capture the interesting features or ideas in the dataset. The dataset was then organised and potential themes were proposed by examining the patterns and connections between codes. Themes were then reviewed and refined, ensuring they are coherent and representative of the data. Each theme was clearly defined and named, making them distinct and accurate. This step was continuously repeated to review and refine the themes for consistency. The analysis was documented by describing each theme with supporting statements from the respondents. This adaptable approach allows for a systematic analysis of qualitative data, aiming to generate meaningful themes that contribute to research understanding, relating to the research question and objectives.

RESULTS AND DISCUSSION

Indicators for the Implementation of Net-Zero Carbon Construction Projects

To comprehend the carbon emission issue on the construction industry, the indicators must first be identified. Figure 2 illustrates the indicators of the implementation of net-zero carbon in construction projects. Eleven subthemes were identified and grouped into three themes that are management, project characteristic, and technology. The management theme has several subthemes, including project lifecycle, maintenance, monitoring procedures, and waste. The subthemes under the project characteristics theme include the surrounding area and types of construction. Finally, the technology theme is subdivided into subthemes that include construction materials, design, energy consumption, machinery and transport. The specifics of each theme are covered in the following sections.

Management

The construction industry can effectively manage and reduce its carbon emissions by considering the project's life cycle, maintaining equipment, implementing monitoring policies, and adopting efficient waste management practices. From the interviews done, it is found that emphasising the understanding of emissions associated with each stage of the project helps to establish effective solutions for reducing carbon emissions. Regular maintenance ensures the efficient operation of equipment, thereby reducing energy waste and emissions. An organised maintenance routine makes it easier to find and fix problems that could lead to

higher emissions. The development of mitigation strategies requires the application of monitoring mechanisms for infrastructure projects moreover for sites located in environmentally sensitive regions. Apparently, this study also found that effective waste management practices including recycling and waste segregation play a crucial role in accomplishing net-zero carbon construction. By maximising recycling efforts, the demand for new raw materials is reduced, thereby lowering carbon emissions and contributing to a more sustainable built environment.

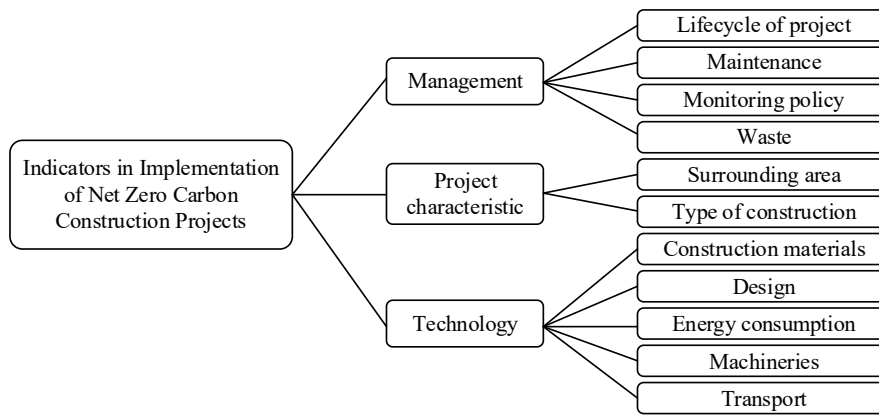


Figure 2: Summary of Indicators in the Implementation of the Net-Zero Carbon Construction Project

Project Characteristic

Understanding the potential carbon emissions associated with a construction project is crucial, and it depends on factors such as the type and location of the project. This understanding enables project planners and stakeholders to effectively identify areas where carbon reduction strategies can be implemented. The result shows that the location of the building site has a big impact on carbon emissions, especially if it is close to a road or highway where there may be more transportation-related carbon release. Additionally, carbon emissions are also influenced by the type of construction, with high-rise structures often releasing higher emissions than other types. However, it is important to note that carbon emissions from high-rise buildings are temporary and mainly occur during the two to three years of construction. Conversely, horizontal developments such as monorails and highways contribute to sustained carbon emissions throughout their operational lifespan.

Technology

By addressing various technological aspects, including the selection of building materials, sustainable design, energy management, machinery utilisation, and

transportation planning, construction projects may significantly advance toward reaching net-zero carbon objectives. The study concluded the crucial role of construction material selection in carbon emission control, promoting eco-friendly alternatives with certified credentials. On-site processes like cement mixing are noted as potential sources of heat and increased emissions. Optimising site plan design becomes imperative for reducing the carbon footprint, enhancing energy efficiency, promoting resource conservation, and facilitating the seamless integration of renewable energy sources. Monitoring energy consumption from primary sources, such as tracking electricity usage through meter bills, allows effective identification of high-energy usage areas. This facilitates the implementation of energy-saving measures, utilizing energy-efficient equipment and adopting renewable energy systems for carbon emission reduction. Accurate measurement of emissions requires converting machinery usage into carbon emission factors. Another factor mentioned is the age of the machineries since the older machine tends to be less effective and produce more emissions than the newer machine. Transportation-related activities record enables project teams to identify opportunities for optimising logistics, reducing travel distances, and exploring sustainable transportation options like electric or hybrid vehicles. As a result, efficient transportation planning significantly contributes to minimising carbon emissions associated with construction-related travel.

Challenges for the Implementation of Net-Zero Carbon Construction Projects

The implementation of net-zero carbon in construction has gained significant attention and importance due to the urgent need to reduce carbon emissions. However, the implementation in a construction project has proven to be a challenge for several reasons as shown in Figure 3. Twelve subthemes were identified and grouped into five themes. Financial, governance, management, people, and technology are the themes of this variable. Cost and profit are two subthemes in financial. Enforcement and policy are the subthemes for governance. The subthemes for management include progress and multiplayer. The subthemes for people are awareness, competency, and mindset. Established technology, mobility, and suitability are the subthemes for technology. The specifics of each theme and subtheme are covered in sections that follows.

Financial

Overcoming the financial challenges associated with implementing net-zero carbon construction necessitates a shift in perspective and a holistic approach to assessing costs and benefits. This study reveals the importance of taking into account the long-term financial savings and environmental advantages that may be realised through decreased energy usage, decreased operational costs, and enhanced sustainability credentials outweighing the possibility of higher initial

expenses. One of the challenges revolves has to do with how expensive it is to buy new, environmentally friendly equipment. Contractors may decide to keep employing old technology and equipment due to the high expense. Additionally, concerns regarding profitability and ROI pose challenges in the implementation of net-zero carbon construction projects. Stakeholders or opponents may show unwillingness to pay the higher expenses involved with adopting sustainable practices, as the financial returns may take longer to materialise.

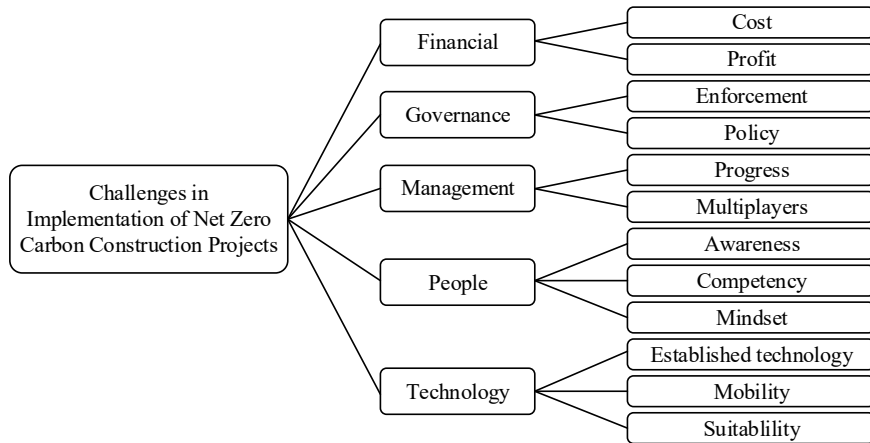


Figure 3: Summary of challenges in the implementation of the net-zero carbon construction project

Governance

Governments should give priority to strong enforcement mechanisms, including monitoring, reporting, and compliance frameworks to successfully handle the challenges in achieving net-zero carbon construction. To develop comprehensive policies that provide a clear roadmap for reaching net-zero carbon construction, this study suggests the importance of collaborating with industry experts, researchers, and relevant stakeholders. However, one of the challenges encountered is the lack of effective enforcement of government policies pertaining to net-zero carbon construction. This challenge arises from various factors, including limited resources, insufficient monitoring mechanisms, and coordination issues among different levels of government. Additionally, another challenge lies in the formulation and clarity of government policies. The shift to net-zero carbon construction must be fuelled by clear and well-defined regulations that outline the targeted reductions in carbon emissions and provide guidelines for implementing green building and construction practices.

Management

Apprehending the management challenges in implementing net-zero carbon construction necessitates a shift in mindset and effective communication among project stakeholders. Environmental officers must actively participate in the project team by presenting the advantages of sustainable practices with clear justifications and supporting data. However, from the respondents' point of view, the challenge arises from the conflict between environmental considerations and the desire to expedite the construction progress. Additionally, this study has also identified another challenge that stems from the lack of awareness and support from other team members. Other team members might not completely appreciate the severity of these concerns, even while the environmental officer is aware of the dangers and necessity of controlling carbon emissions. Cooperation and support from stakeholders, industrial and environmental experts are essential to be developed.

People

Implementing net-zero carbon practices presents several people-related problems that need a comprehensive strategy-based approach. According to the findings of this study, strategies include putting in place education and outreach initiatives catered to various stakeholder groups, removing language barriers, encouraging cooperation and information sharing within the sector, and advocating for supportive policies and regulations. One of the is the lack of awareness among workers and other project stakeholders regarding the importance of net-zero carbon practices. Environmental officers presented at the construction site can promote awareness and provide guidance on sustainable practices. However, language barriers with general workers can pose challenges in effectively communicating awareness and instructions. Another challenge as highlighted by the respondents is the lack of knowledge and expertise to create thorough recommendations for the construction industry on how to properly neutralise carbon emissions. Additionally, a significant challenge lies in the attitudes and mindsets of the individuals involved in construction projects. Although sustainable practices are good for the environment, they may not yield immediate financial benefits, which discourages implementation. Some contractors may only comply with sustainable practices when enforced by authorities.

Technology

Technology-related challenges in implementing net-zero carbon construction practices necessitate a combination of research, innovation, and collaboration. The study identified several challenges, one of which being the restricted availability and uncertainties surrounding green technologies. Given that net-zero carbon construction practices are relatively recent, there may be a lack of expertise in the field and a shortage of professionals knowledgeable in

implementing these technologies. Another challenge arises from the constrained working environments often found on construction sites, which make it difficult to mobilize equipment, particularly larger machinery required for sustainable practices. Furthermore, some construction sites may have restrictions that make it impossible to use certain technology, like solar panels. Factors such as restricted areas or unpredictable weather conditions can affect the feasibility and effectiveness of specific renewable energy solutions.

Strategies for the Implementation of Net-Zero Carbon Construction Projects

In order to achieve net-zero carbon construction, it is essential to establish and implement effective strategies. These strategies aim to balance out carbon emissions and removal by lowering or offsetting the carbon emissions caused by construction projects. The strategies to assist in achieving net-zero carbon in construction are illustrated in Figure 4. Four themes were developed from the sixteen subthemes that were found. The themes of this variable include financial, governance, management, people, and technology. Some of the subthemes under management are maintenance, planning, emission control, reduce, reuse and recycle as well as replanting. Knowledge has subthemes concerning awareness, educate, and training. Governance has three subthemes: enforcement, penalty, and rewards. The subthemes for technology include energy saving, machineries, materials, renewable energy, and sustainable construction. The sections that follow describe the details.

Management

Effective implementation of net-zero carbon construction in the construction sector requires proactive planning, collaborative stakeholder engagement, and a steadfast commitment to sustainable practices. Integrating these strategies into the project management process from early planning stages is crucial for optimizing carbon reduction potential. Maintenance practices, including adhering to a defined schedule and routine checks, such as air filter and exhaust system replacements, are imperative to ensure optimal machinery performance, contributing significantly to emission reduction. A thorough understanding of carbon emission sources in construction projects is essential, necessitating measurement and examination at every project life cycle stage. Emissions control and reduction initiatives, including the use of renewable energy sources such as solar or wind power, are vital for achieving net-zero carbon goals. Waste management practices prioritising reduction, reuse, and recycling are recommended, with construction waste segregation and recycling whenever feasible. Additionally, tree-planting initiatives contribute to carbon neutralization and enhance ecological value by stabilising soil, preventing erosion, reducing landslide risks, and aiding in carbon repossession.

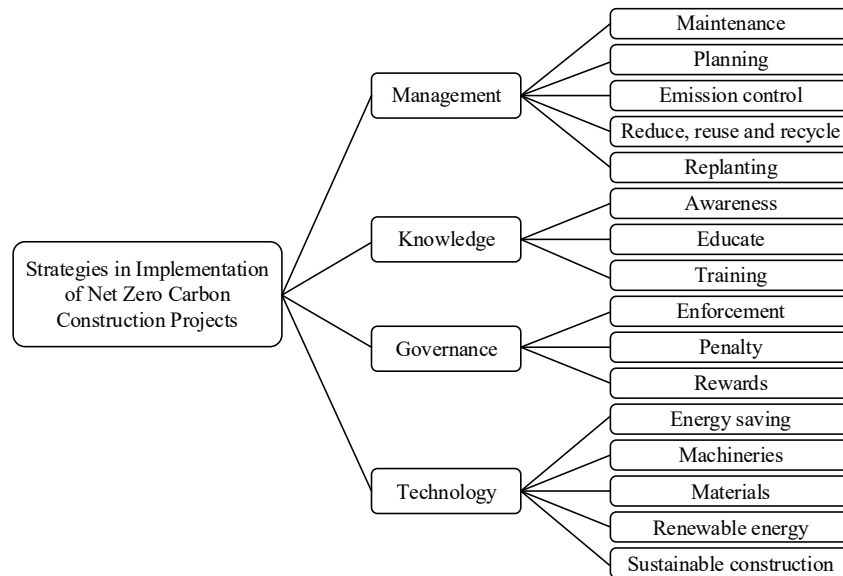


Figure 4: Summary of strategies in the implementation of the net-zero carbon construction project

Knowledge

Implementing strategies for achieving net-zero carbon in the construction industry necessitates a knowledge-based approach that empowers individuals and organizations with the necessary understanding and skills. Based on the results, the construction industry may foster a culture of sustainability and innovation by raising awareness, providing education, and offering relevant training programs. It is profound to raise awareness among all parties involved in construction projects through various means such as courses, workshops, and training programs specifically focused on sustainable construction practices and the importance of reducing carbon emissions. The findings also highlight the importance of universities incorporating subjects relevant to sustainable building in their curriculum, ensuring that future professionals are equipped with the vital knowledge and understanding of net-zero carbon principles. Training and guidance on reducing carbon emissions at construction sites may be provided by organisations such as Malaysian Carbon Reduction and Environmental Sustainability Tool (MyCREST). They may impart knowledge on best practices, technology, and techniques that align with net-zero carbon goals to project teams, contractors, and workers. These programs can focus on specific areas such as energy-efficient design, integration of renewable energy, sustainable material selection, waste management, and carbon accounting.

Governance

Governance strategies play a crucial role in facilitating the implementation of net-zero carbon construction projects by creating a supportive framework. According to the results, these strategies include enacting specific environmental acts, implementing penalties for excessive carbon emissions, and offering rewards for sustainable practices. To effectively address carbon emissions, governments should enact specific environmental acts or regulations that specifically focus on reducing carbon emissions in the construction industry. Existing environmental acts should be carefully reviewed and revised to incorporate clear instructions and guidelines regarding allowable carbon emissions. Penalties or taxes on carbon emissions can serve as a strong motivator for the construction industry to aggressively decrease their carbon footprint. Contractors and project owners should be held accountable for their carbon emissions, and penalties should be imposed if emissions exceed the established baseline. Offering rewards or recognition to project owners who successfully implement measures to reduce carbon emissions can be an effective strategy. Project owners may be encouraged to prioritise and invest in sustainable construction methods through green building certifications or other sustainability certifications. This not only encourages the use of net-zero carbon solutions but also helps projects become more reputable and marketable.

Technology

The construction industry can make substantial strides in reducing carbon emissions, bringing them closer to achieving net-zero carbon goals through the strategic adoption of technology. These strategies encompass various areas, as found in this study, including energy-saving practices, machinery evaluation, sustainable materials, renewable energy adoption, and advanced construction methods. Vital to emission reduction on construction sites, energy-saving practices involve simple yet impactful measures such as powering down equipment during breaks and idle periods. Rigorous evaluation of machinery ensures compliance with environmental and efficiency standards. Exploring alternative materials like green cement or cementless concrete presents a significant opportunity for carbon footprint reduction, with green cement offering lower carbon intensity. The respondents suggested for incorporating renewable energy solutions into construction machinery, emphasizing their role in curbing carbon emissions. Inclusion of specifications for renewable energy technologies in construction contracts serves as an incentive for on-site adoption. Furthermore, embracing modern building techniques such as Industrialized Building Systems (IBS) and Prefabricated Prefinished Volumetric Building (PPVC) contributes to emission reduction by relocating a substantial portion of construction activities to controlled manufacturing facilities, thereby minimizing energy consumption and waste generation.

CONCLUSION

In conclusion, this study emphasises the importance of implementing net-zero carbon construction practices within the construction industry for a greener and sustainable future. It highlights key indicators, challenges, and strategies that are pertinent to this issue. Indicators such as construction type, location, and the influence of diverse construction technologies provide actionable insights into effective carbon reduction strategies. However, the implementation process encounters hurdles such as financial constraints, governance issues, human-related impediments, and technological constraints. Overcoming these challenges necessitates a shift in perspective, effective communication, and collaboration among stakeholders. Proposed strategies encompass proactive planning, infusion of sustainable practices into project management, educational initiatives, training programs, and the establishment of supportive governance frameworks. Attaining net-zero carbon construction mandates the adoption of energy-efficient practices, utilisation of sustainable materials, incorporation of renewable energy solutions, and the integration of advanced construction technologies. Success hinges on collaborative efforts, information exchange, and a shared vision of sustainability among stakeholders. The construction industry, by embracing these practices, can significantly propel itself towards net-zero carbon goals, contribute to greenhouse gas reduction, combat climate change, and forge healthier, more resilient built environments for future generations.

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