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RESEARCH ARTICLE

Barriers and Strategies for Improving Carbon Emissions Management Approaches in Malaysian Construction

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Abstract

A recent study has focused on environmental challenges due to the construction industry's elevated energy consumption and greenhouse gas (GHG) emissions. A more effective low-carbon development implementation relies on proper emissions management throughout the construction industry. The purpose of this research is to investigate current industry practises in managing emissions in construction projects and the driving factors that influence the efficacy of emissions in construction operations. This study relied on information gathering from eighty-three respondents and thirteen expert interviews with stakeholders engaged in construction projects. Emissions management and monitoring are still underdeveloped, despite growing awareness and commitment to developing low-carbon growth. This study's findings also highlighted that the primary constraints to the industry's adaptation of emissions-reduction strategies exist at the institutional, organisational, and individual levels. This article proposed that government support, capacity building, and the development of emissions monitoring techniques and technologies are vital to minimizing emissions. This study contributed to the existing information on the current understanding and practices of the construction sector

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in Malaysia in adopting emissions management, the key obstacles, and recommendations for proper implementation. By addressing concerns regarding promoting low-carbon enhancement and adoption in Malaysia, the findings of this research could assist stakeholders in the construction industry.

Keywords

Barriers; Carbon; Construction; Emissions; Management Practices; Strategy

Introduction

As society becomes more aware of the ramifications of climate change and global warming, the emphasis is transitioning to minimising the environmental footprint of construction projects. Carbon dioxide outputs are typically considered a fundamental factor of climate change. The building and construction sector has been criticised for being a significant source of unregulated GHG emissions. It is no secret that the construction industry consumes a tremendous amount of energy and contributes significantly to global warming gases. Additionally, the building and construction industry is responsible for more than 35% of global energy consumption and nearly 39% of GHG emissions from energy (IPCC, 2015; United Nations Environment Programme (UNEP),(2014). Nevertheless, according to UNEP (2009), the building and construction field has immense opportunity to reduce GHG emissions compared to other main polluting industries. The construction and building industry, as per the UN Environment and International Energy Agency (2017), can save up to 84% of carbon by 2050 through fuel switching, energy efficiency, and renewable energy use.

Malaysia's rapid development has elevated carbon emissions consumption as a component of social stability and economic strength. Based on the Davidson et al. (2020), the country's GHG emissions were 7.27 tonnes per capita, higher than other Southeast Asian nations. Since the initial low level in 1980, Malaysia's GHG emissions have steadily increased, surpassing the global average in 1995 and 2010 with 5.8 and 7.7 metric tonnes of GHG per capita, respectively. In 2016, the value increased exponentially to 8.09 metric tonnes per capita (Zaid, et al., 2015; World Bank, 2016). During the 2015 Paris Climate Conference, the Malaysian government expressed the intent to reduce the GHG emissions intensity by 45% by 2030 (relative to the emissions intensity of GDP in 2005) (Ministry of Energy, Green Technology and Water Malaysia (KeTTHA), 2017). The government has developed a range of initiatives and goals, including policy, procedures, as well regulatory frameworks, to enable an optimum decrease in emissions, with the vision of making Malaysia's way to carbon neutrality in 2050. Malaysia's government is encouraging a low-carbon, green, and climate-resilient economy through implementing national policies and targets.

It is sensible to enhance the environmental productivity of construction activities by mitigating and decreasing GHG emissions throughout the construction stage. Some studies have demonstrated that targeting emissions efforts during the construction phase instead of just the design and operating phases is critical (Guggemos and Horvath, 2006; Pena-Mora, et al., 2009; Bilec, Ries and Matthews, 2010; Carmichael, Williams and Kaboli, 2012; Arocho, Rasdorf and Hummer, 2014). In contrast, the majority of existing research on construction-related emissions focuses on material selection (Chen and Kamara, 2011; Shafiq et al., 2015; Cho and Chae, 2016; Sathanandam, et al., 2017; Omar, 2018), strategies (Tuohy and Murphy, 2015; Kerdan, et al. 2017; Su, et al., 2021), and technologies (Ho, et al., 2013; Shaikh, et al., 2017) to dramatically reduce emissions levels. Nonetheless, whereas various articles have concentrated on measuring embodied carbon across the building's lifespan, there is a limitation to an extensive study on carbon emissions during construction, particularly for onsite monitoring (Acquaye and Duffy, 2010; Kim, et al., 2012; De Wolf, et al., 2017; Hong, et al., 2020). According to Eras et al. (2013), carbon emissions from the construction process are frequently neglected, meaning that stricter monitoring of construction-related emissions is required. Consequently, this study aims to bridge such knowledge gaps by assessing current construction industry emissions control measures and the key underlying factors that contribute to better emissions management practice in construction projects. This paper attempts to accomplish three (3) objectives, which are as follows: 1) to identify current industry practises in managing emissions in construction projects, 2) to assess the key factors of effective emissions management in construction projects, and 3) to recommend solutions for promoting improved practises in managing construction sector emissions in developing countries like Malaysia.

The following is the structure of the paper: the first section provides a literature review of the previous study on construction emissions. The methodology and data collection are discussed in a subsequent section. The conclusion follows a discussion on the significant barriers to emissions management and potential solutions for successfully implementing emissions management in construction projects.

Literature Review

PREVIOUS STUDIES ON CONSTRUCTION EMISSIONS

By using a range of diesel construction tools, construction works yield substantial GHG emissions such as nitrous oxides (N_2O), carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbons (HC), methane (CH_4), and particulate matter (PM). The construction sector has recently drawn much attention owing to the high utilisation and GHG emissions (UNEP, 2006). EPA Clean Air Act Advisory Committee (2006) reported that all types of off-road diesel engines produced approximately 32% NOx and 37% PM emissions during construction activities (Ahn and Lee, 2013). According to Guggemos and Horvath (2006), worksite equipment used in construction operations emits more than 50% of CO_2. Nonetheless, rather than emphasising the construction procedures, attention has increasingly shifted to the operation and design phases (Bilec, Ries and Matthews, 2010). The majority of emissions were generated during the construction period due to the amount of fuel and energy consumed to power the machinery. Consequently, in conjunction with the worldwide push for sustainable growth, there is a need to reduce the environmental impact of the construction and building industry by lowering emissions (Wong, Ng and Shahidi, 2013; Waris, et al., 2014).

The majority of research on construction-related emissions has centred on material selection, approaches, and emission-reduction tools. Many studies have concentrated on estimating embodied carbon using life cycle assessment (LCA) (Avetisyan,Miller-Hooks and Melanta, 2012; Eras, et al., 2013; Noh, et al., 2014). There have been a few studies published on the calculation of emissions from earthmoving procedures using a variety of techniques and frameworks. For example, analyses that involved field measurements include those that were performed by Abolhasani et al. (2008), Frey, Rasdorf and Lewis (2010), Rasdorf et al. (2012), and Hajji and Lewis (2013). Studies by Ahn et al. (2010) and Albohasani and Frey (2013) used the Portable Emissions Measurement System (PEMS) to measure emissions from construction equipment in various classifications, such as bulldozers, excavators, and trucks. Frey, Rasdorf and Lewis (2010) concluded that onboard PEMS fuel consumption and emissions field data is preferable to laboratory dynamometer tests since it reflects actual in-use conditions.

In addition, construction emissions research has developed output estimation methods using multilinear regression (Lewis and Hajji, 2012), and equipment tracking systems (Ahn, et al., 2013; Heydarian and Golparvar-Fard, 2011), and carbon calculators (Hughes, et al., 2011). Discrete event-oriented simulation has also been investigated by some researchers (González and Echaveguren, 2012; Zhang, Zhai and Yang, 2014; Li and Akhavian, 2017; Nadoushani, Akbarnezhad and Rey, 2018) to simulate actual processes. A modelling tool established by (Wong, Ng and Shahidi, 2013; Tang, Cass and Mukherjee,2013) was used to develop a visual depiction of prospective emissions over time to take preventative steps against these emissions.

The emphasis has turned to incorporating optimisation-based methodologies to develop solutions that maximise or minimise study parameters to achieve sustainable construction. This study used a performance tuning approach to evaluate the most cost-effective equipment to employ in fulfilling environmental regulations or indicate the necessity for further device expenditures in lowering project emissions. In the meantime, Moayedi et al. (2019) applied an optimisation model based on a Genetic Algorithm to regulate the environmental performances of construction works, which can be anticipated from the early design phase. Recent research has also incorporated internet of things (IoT)-based technologies for construction productivity monitoring, including computer vision-based algorithms (Kim, et al. 2018; Roberts and Golparvar-Fard, 2019) and multicamera vision-based frameworks (Kim and Chi, 2020). Furthermore, a prior work by Naghshbandi, Varga and Hu (2021) assessed the monitoring and instrument detecting technology strategy.

OVERVIEW OF KEY FACTORS CONCERNING CONSTRUCTION EMISSIONS

Despite several attempts to comply with sustainability policies, the construction industry emits vast quantities of GHG. Various measures have been undertaken to reduce construction emissions. An assessment of prior studies on construction emissions minimisation revealed that multiple reports have oriented on establishing an output estimating method to analyse pollutants from building works. Multiple studies have underlined the need to monitor emissions onsite. These comprise carbon calculator (Sihabuddin and Ariaratnam, 2009), on-site emissions evaluation (Heydarian and Golparvar-Fard, 2011; Ahn, et al., 2013), or computer simulation (Ahn and Lee, 2013; Zhang, Zhai and Yang, 2014).

Additionally, multiple published studies have emphasised limiting equipment productivity as part of measures to minimise emissions. According to a study conducted by Carmichael and Mustaffa (2018) and Mustaffa (2022), lowering equipment idle time and boosting equipment utilisation can enhance productivity while cutting emissions and expenses. Previously, Kim et al. (2012) and Rasdorf et al. (2012) revealed that reducing equipment idle time and addressing adequate equipment maintenance can improve equipment efficiency. Similarly, Szamocki et al. (2019) discovered that reducing idling machinery may minimise pollutants from construction works. As reported by Tang et al. (2013), coordinating operations is more helpful at lowering emissions than working equipment. This investigation suggests that the adjustment in equipment period control did not instantly increase pollution efficiencies. Better management methods, such as task planning, operation planning, and activity planning, may help mitigate onsite emissions (Szamocki, et al., 2019).

Moreover, many experts agree that instituting regulations and policies relating to emissions and environmental repercussions is the most practical tool for engaging regional reduction targets. Thorough emissions monitoring and measurement standards, legislation, and guidelines have been enacted. The California Air Resources Board (CARB, 2009), and Environmental Protection Agency (EPA, 2008) for example, have issued NONROAD and OFFROAD guidelines to achieve a system for calculating emissions for various types of construction tools. Government regulations can significantly facilitate industry perceptions and drive further behavioural change (Carmichael, Mustaffa and Shen, 2018). UNEP (2009) reckon intrinsic incentives like rewards, rebates, loans or grants, or loans strategically urge people.

THE GAPS AND CHALLENGES IN LOW CARBON CONSTRUCTION DEVELOPMENT IN MALAYSIA

The government of Malaysia has established green development guidelines, the National Policy on Climate Change (NPCC), and the National Green Technology Policy (NGTP) to stimulate green and low carbon progression. Multiple initiatives and strategic plans relevant to green growth have been developed, along with a green rating system, green incentives and finance, a green procurement system, and green technology enterprises (Chua and Oh, 2011). A further strategy for incorporating environmentally friendly practises into the acquisition process has been introduced by the government. The MyHijau green procurement effort offers the potential to generate demand for green products, resources, and services in emerging Malaysian markets (Bohari, et al., 2017). The government has enacted many measures to encourage local enterprises to participate in green building and technology initiatives, including the subsidy system, construction levy reduction, and tax benefits (Diyana and Abidin, 2013). Further efforts include Green Performance Assessment System in Construction (GreenPASS), the Low Carbon Cities Framework and Assessment System (LCCF), Malaysia Public Work Department Green Rating Scheme (pHJKR), Green Building Index (GBI), Malaysian Carbon Reduction and Environmental Sustainability (MCREST), and Green Real Estate (GreenRE).

By introducing top-down rules and efforts, the Malaysian government seeks to render the industry's projects more sustainable. However, there are persistent obstacles to addressing the problems from the ground up in different areas. Although sustainability aspects have been included in different government programmes and policies, it is not yet been integrated into Malaysia's construction investment and development activities (Idris, Ismail and Hashim, 2015). The industry delayed implementation of the approaches due to the government's vague policies, and overlapping and fragmented agencies and activities (Algburi, Faieza and Baharudin, 2016). Shari and Soebarto (2017) suggest that Malaysian construction stakeholders are hesitant to adopt a sustainable culture. Construction companies in Malaysia are not required to engage in government initiatives as most are voluntary.

The technology limitation is a serious obstacle to Malaysia's adaptation to low-carbon and green development. Green building materials are not quite as commonly accessible as conventional materials as it is not well-marketed. Most green building products and technology have not yet matured enough for widespread use in many countries (Algburi, Faieza and Baharudin, 2016). This is similar to Malaysia's existing position, in which a broad range of technologies and green materials are inaccessible. Owing to Malaysia's lack of relevant tools, the required technology must be imported regardless of government advances in green technology laws and efforts, including incentive schemes and rebates (Ong, Yusof and Osmadi, 2021).

Despite the availability of evaluation methods for distinguishing green and low carbon products in Malaysia, the rise of low carbon and green materials has remained moderate. Previous Malaysian studies on building and construction emissions focused on the impact of building materials (Shafiq, et al.,2015; Wen,Siong and Noor, 2015; Omar, 2018). According to Ishak, Mustafa Kamal and Yusof (2017), even though green certification is a crucial part of identifying green producers, some firms refuse to acknowledge its worth. This is corroborated by Hafizan, Hussein, and Noor (2021) research, which that revealed industry participation has been restricted given the lack of need for green products. Life Cycle Assessment (LCA) for assessing embodied carbon in construction materials is new in Malaysia (Idris, Ismail and Hashim, 2015; Ishak, Mustafa Kamal and Yusof, 2017). Recent research by Ang and Morad (2013) shows that Malaysia does not impose any regulations that require all businesses to fulfil these requirements as it depends on the client's needs. International standards like LCA are becoming more vital in the country owing to worldwide demand.

Overall, the Malaysian government has undertaken a tremendous effort to promote low carbon growth by launching a variety of policies and projects. In contrast, there has been little collaborative effort put into effective countermeasures for operation on construction sites, and there has been less activity to generalise industry participant's existing ways of applying emissions-reduction approaches. This research intended to address these knowledge gaps by assessing current industry emissions control measures and the underlying factors that contribute to successful emissions reductions in construction works.

Research Methodology

Using a mixed-methods strategy in 2021, this study collected a wide range of data and made it convenient to compare outcomes from various sources. Qualitative and quantitative methodologies are used to gather data from three (3) key sources: site visit, a questionnaire survey, and additional semi-structured interviews. This approach provides a clearer context than the other methods.

This study focuses on the state of Selangor, which is the most developed state in terms of economic development and is regarded as the economic powerhouse of Malaysia (Malaysian Dutch Business Council) (MDBC, 2022). Besides, Selangor is also the spot where the majority of the mega construction projects are carried out. Site visits were conducted at eight (8) construction sites to collect quantitative data on the implementation of carbon emissions management in construction projects. Cross-sectional surveys were then used to gather quantitative data on industry perceptions of understanding and experience with low-carbon practices. Lastly, semi-structured interviews with thirteen (13) experts were performed to obtain professional viewpoints on the most significant restrictions, factors, and approaches for effectively adopting emissions control. The next section summarises the results and findings from each of the three methods of data collecting.

SITE OBSERVATIONS

The top twenty construction businesses in Selangor that are currently engaged in building activities received an invitation letter to take part in this study. The purpose of the study is to examine the factors that influence ongoing construction operations. Only eight (8) of the companies have responded, agreeing to have site visits conducted at respective building sites to collect relevant data. It was necessary to hold a few discussions with the site's management for information and assessment of the implementation level of emissions control measures on the premises. On-site paperwork such as logbooks and inventory lists was examined for statistics about energy usage and the amount of equipment operating time. An independent list was used to build this non-participatory approach to verify emissions management processes. There was no application of the recording's components in any way. The employees have inactively participated in the process of gaining more knowledge that best reflects actual current practises within the scope of this research.

QUESTIONNAIRE SURVEY

Findings from this study will enable the construction industry to comprehend the best ways to incorporate pollution control into projects, as well as the problems and techniques for accomplishing this goal. The primary obstacles and difficulties were drawn from research studies by Carmichael, Mustaffa and Shen (2018) and Joseph and Mustaffa (2021), in addition to earlier research on low-carbon and environmentally friendly practises. The extension of well-known criteria derived from earlier studies helps to boost the relevance of the analysis (Cheng and Li, 2002). Prior to the survey's distribution, pilot questionnaires were conducted with five (5) construction professionals, including contractors, consultants, project managers, and scholars. The final questions were then presented to the target participants in accordance with the responses and insights obtained from the pilot questionnaire. The questionnaire is broken down into three sections:

i. Section A necessitates the participant's profile history.
ii. Section B addresses respondents on existing industry knowledge and procedures for managing emissions in construction projects.
iii. Section C emphasizes the core limitations to emissions management and personal insights from respondents concerning the issue as well as choices for implementing emissions management. A

Likert scale with five points, ranging from "strongly disagree" to "strongly agree," has been structured into sixteen different items (the extent to which the respondents agree to the given statements).

The total number of participants in the survey was drawn from a wide range of construction industry stakeholders in Selangor, Malaysia. Respondents were selected using a non-probability sampling method, known as criterion purposive sampling. A total sample of 384 was selected by using Krejcie and Morgan sampling procedure (Krejcie and Morgan, 1970). This strategy was considered fit since it enables the research to fulfil the study's objectives (Samari, et al., 2013). The following set of predetermined criteria was utilised to pick the construction workers: holding both recent/ongoing and current active involvement in the management of construction sites, as well as significant industry experience (>5 years). Online and postal approaches were used to administer the survey. A response rate of 21.6% has been obtained out of a total sample size of 384 people, including local governments, contractors, project leaders, consultants, site supervisors, site engineers, and developers engaged in building projects. The results of a study by Visser et al. (1996) indicate that studies with minimal response levels, as low as 20%, can generate more accurate findings. Similarly, the results of a national survey demonstrate that response rates range from 5% to 54% (Holbrook, Krosnick and Pfent, 2007). Table 1 summarises the demographics of the survey respondents.

Table 1. Demographic profile of respondents

	Respondent characteristics	No. of respondents (total= 83)
Years of experience	Less than 10 years	28
	Between 11 and 20 years	38
	Between 21 and 30 years	17
Designation	Project managers	11
	Contractors	20
	Consultants	17
	Site engineers	10
	Site supervisors	13
	Local authorities	8
	Developers	4

INTERVIEWS

As part of an explanatory sequential design, semi-structured interviews are used to supplement and explain quantitative data obtained from cross-sectional survey questionnaires and case studies. The rationale for this explanatory process is that quantitative measures and outcomes provide a comprehensive insight into the topic, permitting for a more thorough examination.

Thirteen (13) industry professionals were selected after careful consideration to discuss views regarding the management methods for carbon emissions in the construction business. Project and construction site management experience were taken into consideration when selecting interviewees. There are a total of six roles held by the respondent, including three (3) contractors, three (3) project managers, two (2) engineers, two (2) consultants, two (2) site supervisors, and one (1) developer. The total number of interviews is backed by Skulmoski, Hartman and Krahn (2007), who concurs that between 10 and 15 participants should be interviewed, as well as Guest, Bunce and Johnson (2006) stated that saturation often hits around 12 to 15 individuals in homogeneous groups. Therefore, the validity and depth of qualitative information ought to be relevant to the information richness of the selection and the analytical capabilities, rather than the number of participants in the study.

The following describes the semi-structured inquiries that were designed to allow participants the opportunity to offer personal insights on the effective implementation of emissions reduction measures:

a) The restrictions prevent those involved in the building industry from consistently incorporating emissions management strategies.
b) Initiatives to optimise the performance of emissions management in the construction sector.
c) An intriguing question enables the participant to contribute or address related concerns.

The data sufficiency of data is reached or appeared at a saturation point or redundancy (Strauss and Corbin, 1998), once there is no additional knowledge identified in the last few interview sessions.

DATA ANALYSIS

The percentage frequency distribution, content analysis, mean, standard deviation, reliability analysis, and Pearson correlation analysis were conducted to obtain descriptive statistics.

Reliability Test

The sixteen variable items found in Section C of the questionnaire (strategies and obstacles to practicing emissions management) were subjected to a reliability analysis, which resulted in a Cronbach's alpha score of 0.891. Nunnally and Bernstein (1994) stated that a value greater than 0.70 was deemed acceptable.

PEARSON CORRELATION ANALYSIS

The Pearson product-moment correlation coefficient (r) was employed for normal data in this study to quantify the strength, direction, and likelihood of the linear link between two interval or ratio variables as described by Pallant (2020). Pearson's r can be interpreted as an indicator of the linear relationship in either a positive or negative direction. This measure takes into account the importance of the link between the variables and can take on values that range from –1.0 to +1.0. There was a positive correlation between variables when the trend had a comparable direction, regardless of whether it was an increase or decrease. An essential outcome of this study was the existence of a strong link between implementation challenges and carbon emissions reduction techniques.

The strength of the correlations is determined by the Pearson coefficient's absolute value. The following are the rules for interpreting the strength of association, as outlined by Cohen (1988):

If .10 < l r l < .3, the value is regarded small having a poor relationship.

If .29 < l r l < .49, value is deemed medium having a moderate relationship.

If .5 < l r l < 1.0, value is considered high having a strong relationship.

Content Analysis

Analysing information is an extensively used qualitative research method that counts the numerous features of a given piece of information to provide a brief description. It is divided into three major strategies: summative, conventional, and directed (Hsieh and Shannon, 2005). This inquiry used standard content analysis. The data gathered served as the foundation for the creation of the basic coding template. This necessitated an exploratory method in which the codes were organised and rearranged until a set of themes developed that represented the data's basic patterns and connections (Saunders, Lewis and Thornhill, 2016). This procedure permitted the key theoretical premises to be further integrated as it was established to reflect and examine major themes also linkage in the data. Thus, participant responses were analysed by shifting raw narrative data (notes, audiotapes) into semi-processed data (transcripts) and manually transcribing it.

Results and Discussion

This part comprises the data gathering on participants' comments through questionnaire forms on the participant's degree of comprehension of the necessity of emissions management ideas and existing practices. Percentage frequency distributions were applied to analyse the data from the study.

AWARENESS OF THE IMPORTANCE OF EMISSIONS MANAGEMENT IN CONSTRUCTION PROJECTS

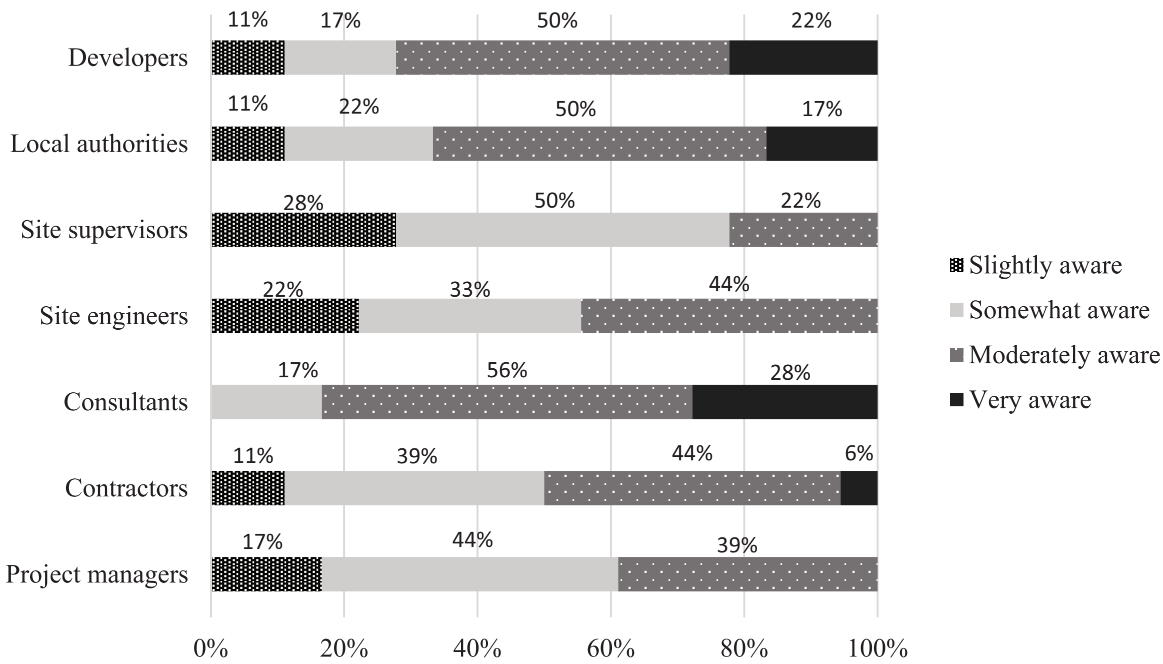

Figure 1. Awareness of the importance of emissions management in the construction project

The respondents were questioned regarding their level of familiarity with the idea of low carbon as well as the government's goal of reducing emissions by 45% in the year 2030. Figure 1 portrays that consultants are more conscious of the implications of the low-carbon paradigm than contractors, developers, local governments, and project managers. This could imply that consultants with responses of 'moderately knowledgeable' and 'very aware' (84%) have a greater grasp and knowledge of engaging with low carbon and green development than developers (72%) and local governments (67%). In contrast, when asked about the necessity of mitigating emissions in construction operations, site supervisors (78%), project managers (61%), and site engineers (55%) were either 'slightly aware' or 'somewhat aware,' reflecting the inadequate information. Further research revealed that, while the majority of respondents were exposed to low-carbon ideas through seminars, webinars, and a capacity-building programme initiated by the government to promote green development in Malaysia, the volume of information gleaned is conceptual and idea-based, causing it tricky to impose to real-world project implementation.

DO YOU CONSIDER PRACTICING EMISSIONS MANAGEMENT IN CONSTRUCTION PROJECTS?

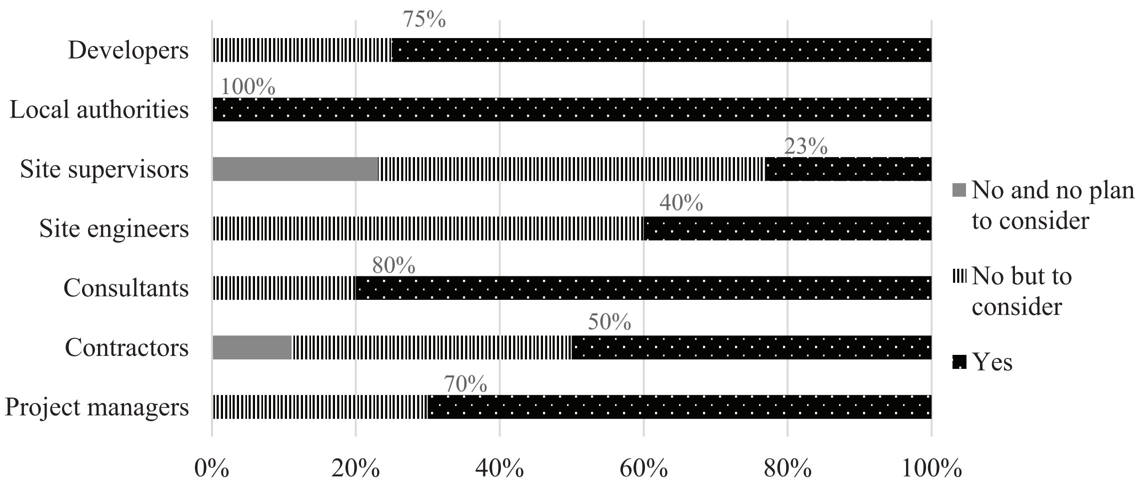

Figure 2. Consideration of the emissions management implementation

Besides, Figure 2 shows that the vast majority of respondents approved including emissions mitigation in the construction projects. In the meantime, half of them are still debating whether to go forward and implement it. Nonetheless, approximately 4% do not practise emissions management and thus have no intentions to do so. These data confirm that employee attitudes differ, and the industry's readiness to evolve is contingent on its conviction in the consequences of necessary changes (Wong, Ng and Shahidi, 2013).

WHO DO YOU BELIEVE SHOULD ULTIMATELY BE MOST RESPONSIBLE FOR EMISSIONS MANAGEMENT IMPLEMENTATION IN A CONSTRUCTION PROJECT?

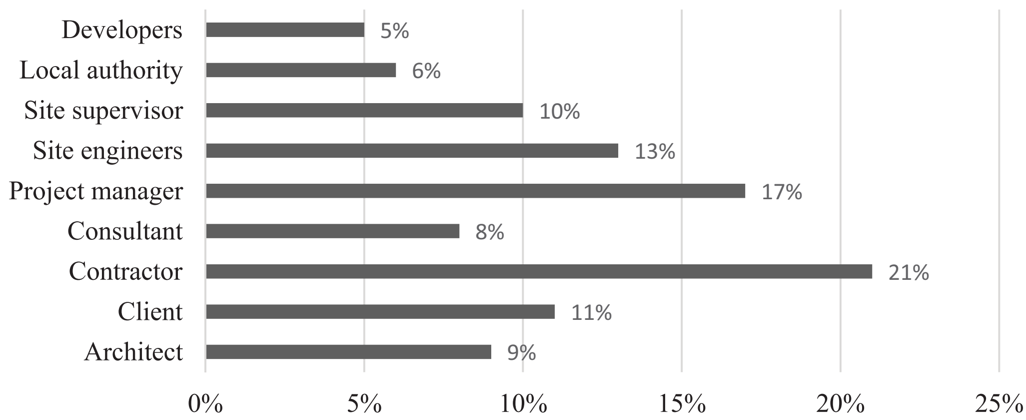

Figure 3. Professions are believed to be the most responsible for emissions management in construction projects.

The construction project's best practises for emissions control are shown graphically in Figure 3. Participants were asked to consider which occupations should oversee ensuring project emissions. The findings indicate that contractors (21%) were voted as the most liable for decreasing construction emissions. The project manager (17%) and site engineers (13%), for instance, play a significant role in carbon reduction on the construction site. This signifies that these positions were directly involved on the construction site.

EMISSIONS MANAGEMENT PRACTICES IN CONSTRUCTION PROJECTS

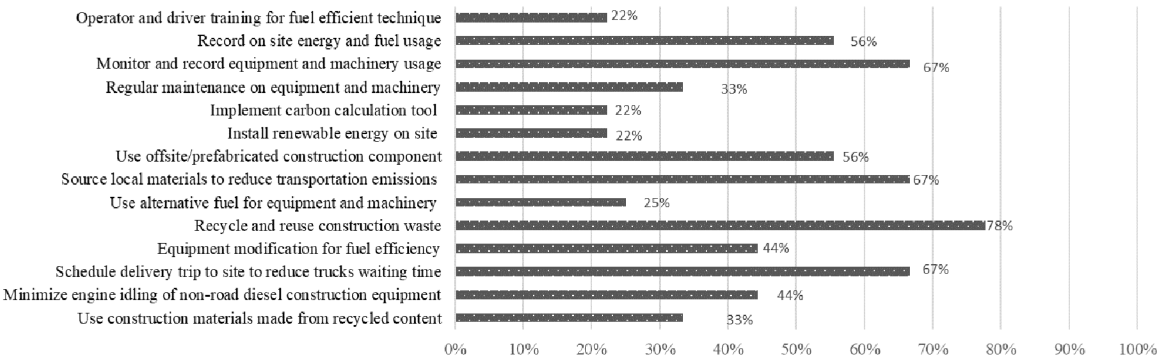

Figure 4. Emissions management practice in construction projects

Figure 4 displays construction project emissions management strategies. In general, the majority of construction players have used emissions control in their projects. Roughly 78% of construction site managers reuse and recycle construction debris. Moreover, 67% of them answered to monitor and document the on-site tools and machinery used, organise delivery trips to the site to reduce truck waiting time, and source locally available materials to reduce transportation emissions. Another 56% of site managers claim to track on-site energy and fuel consumption, as well as use offsite/prefabricated construction components. On the other side, little effort was discovered on measures like alternative fuel use, on-site renewable energy installation, fuel-efficient method training, and the implementation of carbon calculation tools. Overall, the application of emissions control in building projects is still low, despite prior measures to regulate the site's outputs. This study's findings contribute to current knowledge (Ghazali and Zahid, 2015), revealing that, while there is a rising commitment to environmental sustainability, real practise in controlling and managing emissions remains remarkably low. Similarly, most firms have just made assertions about their attempts to reduce CO_2 emissions, without providing any actual data on carbon emissions. According to Nejat et al. (2015), establishing emissions reports obligatory will drive the industry to assess and cut emissions.

SURVEY QUESTIONNAIRE FINDINGS

The participants were required to provide their views on the constraints to incorporating emissions management in infrastructure projects and the carbon strategies enacted by their organisations.

BARRIERS TO IMPLEMENTING EMISSIONS MANAGEMENT

Table 2. Descriptive statistics of the mean (M) and standard deviation (SD) for the barriers to emissions management implementation

Key barriers in implementing emissions management	Mean	Std. Deviation	Rank
Lack of awareness and interest in the significance of emissions and the implications on the environment.	3.9742	1.1790	1
Lack of technical knowledge and skills in mitigating emissions and adopting green technology.	3.3291	1.2060	6
Resistance to change from the use of traditional methods and techniques.	3.3291	0.9958	6
Lack of information on the availability of alternative construction materials and products and green technologies available in the market.	3.5570	0.9362	4
Lack of organisation's commitments toward sustainability.	3.2532	1.0916	8
Environmental target is not included in the company's objective.	3.1882	0.9573	9
Lack of tools and mechanisms to monitor emissions management implementation in the construction project.	3.7368	1.0637	3
High costs for low carbon products, materials, and green technologies.	3.8354	0.9928	2
Lack of information on the government's initiatives on emissions.	3.5570	0.9325	4
The limited resource to invest in implementing emissions mitigation strategies.	3.4735	1.4315	5
Lack of enforcement and mandatory requirement in emissions mitigations.	3.2658	1.0785	7

The limitations are ranked based on mean values to determine the most significant challenges that respondents encountered while adopting emissions management in the construction industry. According to the results of the survey, the prime serious obstacle is a "lack of awareness and interest in the relevance of emissions and the effects on the environment" (M=3.9742; SD =1.1790). 'High costs for low carbon products, materials and green technology' (M=3.8354; SD=0.9928) was the second-highest rated issue. Furthermore, 'the absence of instruments and framework to monitor emissions management performance of a construction project' (M=3.7368; SD=1.0637) ranked third on the list. Moreover, a shortage of information on the existence of alternative building materials, products, and green technologies accessible in the market was mentioned as an obstacle to reducing emissions in a project. The respondents appear to be unsure about the types of environmentally friendly and low-carbon technologies to implement in their construction projects. However, they have expressed an interest in gaining additional knowledge on the implementation of low-carbon technologies in future building projects.

On the basis of the responses, critical obstacles to the implementation of carbon emissions controls have been categorised into three (3) different groups: institutional, organisational, and individual for improving emission planning and management.

Table 3. Summary findings of key challenges hindering successful emissions management

Key barriers	Key findings
Institutional/ Government	• Lack of tools and mechanisms to monitor emissions management implementation in the construction project. • Lack of information on the government's initiatives on emissions. • Lack of enforcement and mandatory requirement in emissions mitigations.
Organisational	• High costs for low carbon products, materials, and green technologies. • Limited resources to invest in implementing emissions mitigation strategies. • Lack of organisation's commitments toward sustainability. • Environmental target is not included in the company's objective
Individual	• Lack of awareness and interest in the significance of emissions and the implications on the environment. • Lack of information on the availability of alternative construction materials and products, and green technologies. • Lack of technical knowledge and skills in mitigating emissions and adopting green technology. • Resistance to change from the use of traditional methods and techniques.

CARBON REDUCTION STRATEGIES

Five (5) carbon reduction strategies were proposed to the respondents to rate based on their professional opinions. Table 4 shows the descriptive statistics of the mean (M) and standard deviation (SD) correlations and Cronbach's alpha reliability coefficients of the construct measured.

Table 4. Descriptive statistics of the mean (m) and standard deviation (sd) for carbon reduction strategies

Carbon reduction strategies	Mean	Std. Deviation	Rank
Uniform policies and stricter standards: Introducing carbon disincentives schemes or carbon regulations for direct emissions mitigation in construction projects.	3.5696	1.0462	3
Rewards and incentives: Rewarding schemes and incentives to motivate construction companies to implement energy savings or emissions-reduction technologies like tax rebates, capital subsidies, and loan schemes.	3.7215	1.0119	1
Monitoring tools and mechanism: National/ industry carbon inventory and standardized monitoring mechanism act as a reference to the industry to benchmark, monitor and report their emissions.	3.5949	1.0318	2
Promotion and education: Promotion, training, and education that a company can receive from the government or professional institutes on carbon management strategies.	3.5570	0.9967	4
Project planning and management: Incorporate emissions targets in operational and activity planning.	3.3165	1.2252	5

'Rewards and incentives' (M=3.7215; SD=1.0119) were deemed to be the most important strategy when respondents were asked to rank the strategies. Meanwhile, 'monitoring tools and mechanisms' (M=3.5949; SD=1.0318) is the second crucial component. Another key driver identified by respondents is the approach of 'uniform policies and tougher standards' (M=3.5696; SD=1.0462), which is followed by 'promotion and education on the carbon management methods' (M=3.5570; SD=0.9967) and 'project planning and management' (M=3.3165; SD=1.2252), respectively.

INTER-CORRELATIONS BETWEEN BARRIERS AND STRATEGIES BASED ON MEAN RANKING

This study employed Pearson's r to calculate the strength, direction, and probability of a linear relationship between two variables (barriers and strategies). Using data from Table 5, this research shows the moderate and high correlations between the top-ranked techniques and barriers. The selected values for the Sig (2-Tailed) bold statistic are either lower than or equal to .05. A statistically substantial correlation between these factors may be deduced, suggesting that higher or lower barriers are linked to increasing or decreasing strategy.

Table 5. A consolidation of the descriptive statistics based on mean ranking and inter-correlations between the carbon reduction strategies and the barriers (constructs) measured

	Rank	1	2	3	4	5	6	7	8
Rank	Carbon reduction strategies and Barriers	Lack of awareness	High costs	Lack of tools and mechanisms	Lack of information (policies and standards)	Lack of information (alternative materials and products	Resistance to change	Lack of technical expertise	Lack of organisation's commitments
1	Rewards and incentives schemes	-	**.459****	-	.260*	.224*	-	-	**.581****
2	Monitoring tools and mechanism	-	**.440****	**.301****	-	.255*	-	**.459****	-
3	Uniform policies and stricter standards	-	.260*	.298**	**.412****	-	-	.271*	**.562****
4	Promotion and education	**.326****	-	.278*	**.346****	**.346****	-	**.528****	.251*
5	Project planning and management	-	**.329****	.291**	**.349****	**.325****	-	-	.266*

Following the top-rated strategies, it is apparent that both variables have a strong correlation;

1. Increased incentives (r=.581; p<0.05) for construction firms that employ energy savings or emissions-reduction innovations like tax rebates, capital subsidies, and loan schemes (r=.459; p<0.05) boost the organization's commitment even though this could also indicate higher expenses for low carbon products, materials, and green technologies.
2. However, a rise in the use of carbon inventory monitoring tools and mechanisms may improve technical expertise, knowledge, and skills in mitigating emissions as well as adopting

green technology (r=.459; p<0.05), while this would also imply additional fees for low carbon materials, products, and green technologies (r=.440; p<0.0).

3. The organization's commitment will grow if uniform policies and tougher standards on carbon disincentives schemes or carbon regulations are introduced for direct emissions mitigation in building projects (r = 0.562; p<0.05). This will also strengthen the data regarding the availability of alternative construction materials and goods and green technologies that are currently on the market (r =.412; p<0.05).
4. A company's ability to receive government or professional institute-sponsored training and education on carbon management strategies indicates an increase in technical expertise, knowledge, and skills in mitigating emissions and adopting green technology (r=.528; p<0.05), as well as information on policies and standards and alternative materials and products (r=.346; p<0.05).
5. Even though this would indicate higher prices for low carbon products, materials, plus green technologies, strong capacity in project planning and management increases the information connected to regulations and standards (r=.349; p<0.05) as well as information on alternative materials and products (r=.325); p<0.05).

INTERVIEW FINDINGS

An exchange of questions and answers with thirteen (13) recognised authorities in the sector yielded more insights about the removal of obstacles to the implementation of emissions management strategies. As shown in Table 6, the classification of solutions to linked concepts or issues aimed to increase understanding of the findings of the in-depth interviews. These emissions plans are based on the insights of the participants and aim to boost the efforts of the concerned stakeholders.

Table 6. Emissions strategies are based on participant's opinions to improve stakeholder's effort

Key strategies	Respondent's opinions	Key responsibility
1. Uniform and relevant policies and stricter regulation and standard	*-Introducing carbon disincentives schemes or carbon regulations in construction projects would improve the current state of scenarios in construction project and consequently will encourage and motivate stakeholders in monitoring their construction emissions seriously.* *-More stringent construction regulations of construction procurement and mandatory reporting process should be implemented to achieve construction emissions standards.*	Government, local authority
Beneficial programmes and incentives	*-The implementation of beneficial programmes and incentives, such as tax refunds, capital subsidies, and loan incentives to encourage construction companies to adopt emissions measures and green technologies application in their project.*	Government, banks, financial institutions
Promotion and education	*-Educating, promoting, and creating awareness on environment concerns, emissions management techniques and green technology application will generate interest among construction stakeholders to start monitor their construction emissions.* *-In a mission to apply for emissions measures and green technology, it is important for them to leverage their skills and knowledge through training to cope with up-to-date technologies.*	Construction companies, government, semi-governmental agencies, NGOs, educational institutes.

Table 6. continued

Key strategies	Respondent's opinions	Key responsibility
Monitoring tools and mechanism	*-The establishment of national/ industry carbon inventory and standardized monitoring mechanism such as carbon calculator will help the industry to benchmark, monitor and report their emissions production.* *-Although they are committed to start monitor the emissions; however, they are not very sure with the right mechanism to be adopted.*	Government, construction stakeholders, academia and research institutes
Project planning and management	*-Incorporating emissions target in operational and activity planning will direct the company towards effective emissions monitoring process.* *–Implement sustainable site management to effectively manage waste, material, resource and equipment would also contribute to emissions.*	Construction stakeholders

Respondents have suggested five (5) emissions management strategies. Introducing 'uniform and relevant policies and stricter regulation and standard,' 'beneficial programmes and incentives,' 'promotion and education,' 'monitoring tools and mechanism,' and 'project planning and management' were highlighted as crucial drivers in developing effective emission mitigation strategies in construction operations.

DISCUSSION: A WAY FORWARD ON THE BETTER EMISSIONS MANAGEMENT PRACTICE

This section provides recommendations for boosting the effectiveness of Malaysia's emissions management frameworks predicated on the triangulation of outcomes from the eight (8) site observations, a survey administered to eighty-three respondents, and interviews involving thirteen experts. The data from the interviews and the surveys were cross-checked to ensure a sufficient degree of saturation. The themes of the strategies presented here are centred on two-tier plans that reflect top-level and bottom-level measures to expedite emissions control in the construction industry, in response to the major obstacles revealed in this study. Figure 5 displays the basis for emissions management approaches in the construction sector.

Initiatives taken at the highest level of government indicate strategies for overcoming limitations imposed by institutions at lower levels. Due to this, a more effective strategy for managing emissions relies heavily on government policy. The findings demonstrate that the organisational commitment grows by offering more incentives like tax refunds, capital subsidies, and loan schemes to the construction firms. These measures will push them to deploy technology that saves energy or reduce emissions, even though doing so would result in increased costs for low-carbon products, materials, and green technologies. In addition, policies, laws, and standards; benefits programmes and incentives; and capacity training are three important components of the government's participation in converting the country to low-carbon construction.
In parallel with the government of Malaysia's goals to reduce greenhouse gas emissions by 45% by 2030 (relative to the 2005 emissions intensity of GDP) (Susskind, et al. 2020) and establish a carbon-neutral nation by 2050, the government has launched several programmes, including financial support, promotional tactics, legislation, and action plans (Mustaffa, Isa and Ibrahim, 2021). In addition, the government has set a target to reach a carbon-neutral country by 2050. 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. Construction projects must implement mandatory GHG disclosure as a proactive measure to reduce emissions. This can be accomplished by adopting penalties, a carbon tax, a cap-and-trade system, and carbon trading on businesses that surpass

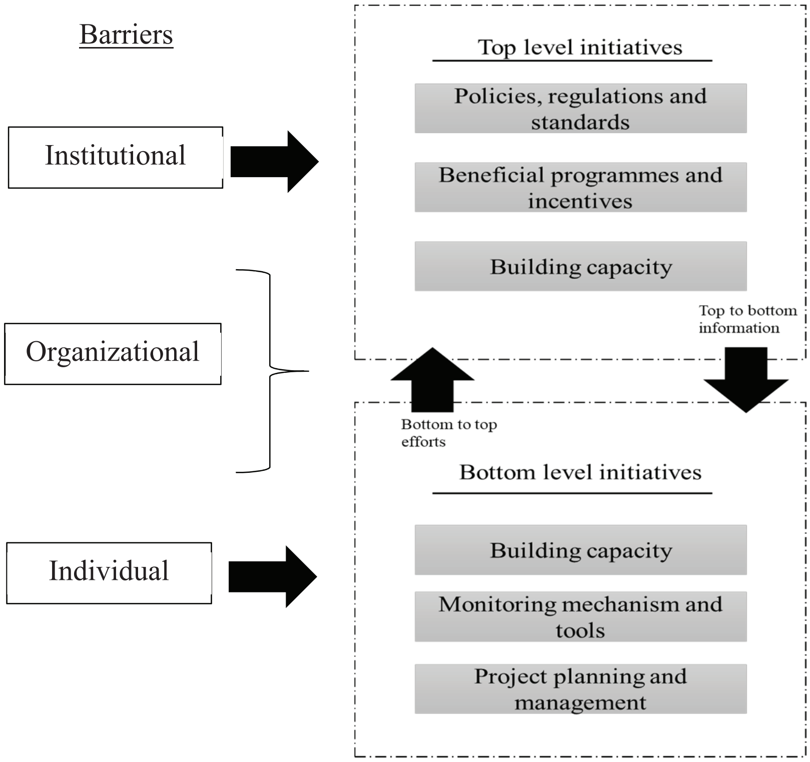

Figure 5. Emissions management strategies framework in the construction industry

the mandated GHG limit that the government established, as well as by establishing more severe building requirements, such as energy performance specifications, building standards, and equipment specifications.

The use of positive incentives, like awards, subsidies, grants, or loans, is more effective than the use of negative compensation, such as fines, at motivating and changing the behaviour of an industry. These many types of incentives have the potential to persuade industry workers to carry out effective strategies for reducing emissions and achieving the emissions targets as well as the national goals that have been set. Relying on previous research, this study confirms the findings of Karkanias et al. (2010) as well as Diyana and Abidin (2013). Furthermore, a disincentive strategy based on their procedures and actions must be established to decrease carbon emissions. According to the findings, an increase in the use of monitoring tools or techniques and mechanisms for the national/industry carbon inventory and standardised monitoring mechanisms act as a reference to the industry to benchmark, monitor, and report their emissions may strengthen the technical expertise knowledge and skills in mitigating emissions as well as adopting green technology. Despite the fact that this would also indicate higher costs for low carbon products, materials, and green technology, the findings show that this may enhance the technical expert knowledge, and skills in mitigating emissions, and adopting green technology.

Among the most important factors in the development of effective methods to reduce emissions is enhancing the level of information and insight held inside the sector. Following the results obtained, increasing the amount of promotion, training, and education that is provided to construction companies by the government or professional institutions on carbon management strategies will boost the technical expertise, knowledge, and competence in mitigating emissions and implementing green technology. This will, in turn, improve the relevant data associated with guidelines and regulations, as well as alternative materials and products. Malaysia's low-carbon policy compliance could be aided by an informed government planning and knowledge management approach (emissions evaluation tools, green building processes). Moreover, the building of institutional capacity can be used to improve an organization's capabilities and foster a culture that is more conducive to low-carbon, climate-resilient growth. Educating decision-makers, construction stakeholders, and other professionals regarding the recent technological breakthroughs and innovative emissions reduction practises will contribute to addressing these concerns. For strategic emissions control purposes, Mustaffa, Isa and Ibrahim (2021) emphasised the importance of enhancing knowledge and skills, as well as a platform for managing data on benchmarks for energy savings or emissions-reduction technology. Kim et al. (2012) and Rasdorf et al. (2012) suggested that equipment operators receive emissions training to limit the amount of fuel combustion that occurs during construction.

The bottom category includes organisational and individual actions aimed at promoting the government's goal of low-carbon growth. This level of capacity utilisation is a major contributor to greenhouse gas emissions. A practical monitoring system and onsite emissions criteria for individual sites and activities can only be implemented on time if the industry undergoes technical and knowledge upskilling on emissions management. This is necessary to make sure that the industry is capable of complying with the carbon emission regulations. Project planning and management skills can increase information on rules and standards, alternative materials, and goods, even if this means greater expenses for low-carbon products, materials, and green technology. Efficient emissions mitigation techniques in construction hence necessitate well-trained project managers with experience in emissions managing and monitoring at the construction site.

Mandating the reporting of carbon emissions will encourage companies to combat climate change to avoid bad publicity and maintain their strong brand images. Additionally, this study found that the government's ability to gather data and develop a national emissions inventory relies on the industry's reporting of carbon emissions and disclosure of carbon emissions reports. Sustainability in site management not only reduces emissions, but also preserves resources, materials, and equipment. In addition to reducing waste and utilising renewable energy, these strategies also take into account embodied carbon and managing water resources.

The findings of this study have contributed to a better grasp of the construction industry's knowledge and practises in integrating emissions management, as well as the key obstacles to effective implementation of emissions management and recommendations for emissions control. The policies and performance of carbon emissions management in the Malaysian context have been addressed in previous studies (Bohari, et al., 2015; Algburi, Faieza and Baharudin, 2016; Ohueri, Enegbuma and Kenley, 2018), however, this research adds to knowledge by identifying the industry's acceptability and the key factors contributing to successful emission control in construction operations. More realistic viewpoints on how low carbon growth affects industry behaviour and commitments to better emissions management methods in Malaysian construction projects have been discovered through this work. As a consequence of this, the research constructs a motivating resonance among the top to bottom information and bottom-to-top efforts solutions to enhance low-carbon growth in Malaysian construction. Figure 5 presents this finding as an illustration of a paradigm for emissions management solutions in the construction industry.

Conclusion

In an attempt to bridge the information gap, this study explores existing industry pollutants management strategies in construction and the limitations and alternatives for efficient emissions in construction work. This study's triangulation of information was assisted through a field survey of eight (8) construction sites, replies from eighty-three construction participants acquired from the questionnaire, and thirteen expert interviews. The first findings from current emissions management practises reveal that, while there is a growing awareness and commitment to low-carbon development, actual practise in controlling and managing emissions remains relatively minimal. Furthermore, the most major challenges to better emissions practises occur at all levels, including institutional, organisational, and individual. Though the country's ambition for a low-carbon future is encouraging, its success is dependent on the cooperation and collaboration of all stakeholders. This research emphasised the proposed interventions to overcome the constraints. Premised on triangulation of findings, a framework displaying top- and bottom-level efforts was established. In accordance with the proposed technique, the nation's goal should be translated into a successful emissions target by upgrading legislation, establishing beneficial programmes and incentives, and increasing building capacity at the highest level. Building capability, establishing monitoring tools, and competent project design and management will augment top-level initiatives to accelerate Malaysia's low-carbon construction transition.

The finding of this research could be beneficial in addressing particular concerns regarding low-carbon adoption and establishing effective methods for achieving low-carbon progress in Malaysia. This study makes a significant contribution of insight pertaining to the industry's prior knowledge and strategies in integrating emissions management in a construction project, as well as the key challenges and factors associated with the management in Malaysia.

This study's ramifications encompass offering more valuable information about the current industry's low-carbon development goals and what it would take to boost emissions control in construction projects. Moreover, the research outcomes could serve as a framework for further discussion on promoting awareness at all levels to accomplish Sustainable Development Goal (SDG) 13: Climate Change. This is also necessary for supporting the government›s aspirations to become a low-carbon nation, as highlighted in the Twelfth Malaysia Plan 2021-2025.

Nevertheless, certain restrictions pertain throughout this study. Since this study relied primarily on statement-based research approaches, no actual figures on CO_2 emissions from building sites could be obtained. Future studies on emissions should incorporate actual data from construction sites to smooth out the findings. This study has a small number of participants and is only based on purposeful sampling from the specified area of Selangor, Malaysia. As a result, the findings of this investigation cannot be extrapolated beyond the boundaries of the scope of this study. Therefore, as Malaysia's emissions management practises continue to evolve, future research may expand the existing population to a bigger extent. A sampling approach that is random, stratified, clustered, or other recognised probability sampling approaches must be used to make generalisations from the larger population. Ergo, further research should engage a wider range of stakeholders, particularly policymakers and stakeholders, for producing better relevant data that offer greater insights into the deployment of low-carbon initiatives.

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