ECO-INNOVATION MOBILISATION FRAMEWORK FOR CONTRACTORS IN GREEN DEVELOPMENT PROJECTS

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UNIVERSITI SAINS MALAYSIA

2023

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by

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Thesis submitted in fulfilment of the requirements
for the degree of
Master of Science

September 2023

ACKNOWLEDGEMENT

All praise to Allah the Almighty for giving me the strength, patience, and courage to complete this level of education. For my beloved husband and my dear family, thank you for the du'a, and the support in any forms. To my respected supervisor, Assoc. Prof. Dr. Nazirah Zainul Abidin, thank you for your patience, empathy, ideas, and guidance that you have provided throughout my Masters degree journey. This appreciation is also addressed to the Ministry of Higher Education for Fundamental Research Grant Scheme with Project Code: FRGS/1/2018/SSI11/USM/02/4. I am also grateful to Universiti Sains Malaysia, School of Housing, Building and Planning (HBP) and Institute of Postgraduate Studies (IPS) for providing and serving all the needed facilities and resources for this research. For my fellow postgraduate comrades, Wani, Syaza, Kak Farah, Kak Sarah, Lai Kee, Ayisha, and Izzat, thank you for the moral support and encouragement at any phase of this study. I am also forwarding my gratitude to all respondents who have participated in my research. Obtaining willing respondents was not easy, especially during the pandemic, but with your kind support, this research is made possible. For my dear self, thank you for your efforts and sacrifices. We did it!

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LIST OF ABBREVIATIONS

3D	3-Dimensional
5D	5-Dimensional
AI	Artificial Intelligence
BEPAC	Building Environmental Performance Assessment Criteria
BIM	Building Information Modelling
BREEAM	Building Research Establishment Environmental Assessment Method
C&D	Construction and demolition
CAD	Computer-aided design
CIDB	Construction Industry Development Board
CITP	Construction Industry Transformation Programme
CNC	Computer numerically controlled
CO2	Carbon dioxide
EACG	Energy Audit Conditional Grant
EI	Eco-innovation
EIA	Environmental Impact Assessment
EMS	Environmental Management System
FRGS	Fundamental Research Grant Scheme
GBI	Green Building Index
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geological Information System
GPS	Global Positioning System
GREEN PASS	Green Performance Assessment System
GreenRE	Green Real Estate
GTMP	Green Technology Master Plan Malaysia
HK-BEAM	Hong Kong Building Environmental Assessment Method
IBS	Integrated Building System
IEQ	Indoor Environment Quality
IoS	Internet of Services
IoT	Internet of Things
KeTTHA	Kementerian Tenaga, Teknologi Hijau dan Air
LED	Light emitting diode
LEED	Leadership in Energy and Environmental Design
LEV	Local Exhaust Ventilation
MCO	Movement Control Order
MDS	Material Data Sheet
MIDA	Malaysian Investment Development Authority
MyCREST	Malaysian Carbon Reduction and Environmental Sustainability Tool
OECD	Organisation for Economic Co-operation and Development

PH JKR	Skim Penilaian Penarafan Hijau Jabatan Kerja Raya
R&D	Research and Development
RFID	Radio Frequency Identification
RMT	Resource Mobilisation Theory
SDG	Sustainable Development Goals
SMART	Stormwater Management and Road Tunnel
SME	Small and Medium Enterprise
UAV	Unmanned Aerial Vehicles
USM	Universiti Sains Malaysia

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RANGKA KERJA MOBILISASI EKO-INOVASI KONTRAKTOR DI PROJEK PEMBANGUNAN HIJAU

ABSTRAK

Konsep eko-inovasi (EI) mampu menangani isu kompleks antara sektor pembinaan dan alam sekitar bagi memulihkan keseimbangan antara kedua-dua elemen. Kesan kadar inovasi yang perlahan dalam sektor ini menekankan keperluan untuk kontraktor menggunakan langkah EI bagi mengurangkan kesan negatif ini dan mewujudkan pendekatan yang lebih mampan bagi membina sambil memaksimumkan nilai ekonomi. Melalui Teori Mobilisasi Sumber Daya, penyelidikan ini bertujuan untuk membangunkan rangka kerja mobilisasi eko-inovasi kontraktor di projek pembinaan. Kajian ini mempunyai tiga objektif iaitu penentuan komponen EI di projek pembinaan dalam skop kerja kontraktor, mengkaji keadaan yang mempengaruhi mobilisasi EI di projek, dan mengkaji strategi kontraktor dalam menggerakkan amalan EI di projek pembinaan. Melalui kaedah kualitatif, temu bual telah dijalankan bersama dengan 15 orang kontraktor yang terlibat dalam pembinaan projek pembangunan hijau. Hasil kajian mendapati bahawa komponen EI dalam skop kerja kontraktor terdiri daripada EI produk, EI proses, dan EI organisasi. Manakala keadaan yang mempengaruhi mobilisasi EI ialah keupayaan firma, sifat projek, dan pemboleh luaran. Strategi kontraktor untuk menggerakkan EI ialah permodalan insan, kolaborasi pintar, penyebaran maklumat, pelanjutan polisi syarikat kepada pelaksanaan projek, pengukuhan prosedur dokumentasi, dan pengoptimuman teknologi. Hasil kajian ini dijangka dapat memberi panduan kepada semua pihak mengenai perkara EI di projek, selain meningkatkan sektor pembinaan Malaysia untuk berkembang maju dalam amalan inovatif sambil menerima pakai pembinaan mampan.

ECO-INNOVATION MOBILISATION FRAMEWORK FOR CONTRACTORS IN GREEN DEVELOPMENT PROJECTS

ABSTRACT

The concept of eco-innovation (EI) addresses the complex issues between the construction sector and the environment to restore the balance between both elements. The impacts of a slow rate of innovation within this sector emphasise the need for contractors to use EI measures to reduce these negative effects and create a more sustainable approach to constructing while maximising economic value. Using Resource Mobilisation Theory, this research aims to develop the contractor's eco-innovation mobilisation framework for construction projects. It has three objectives focusing on determining the components of EI at construction projects within the contractor's scope of work, examining the conditions that influence EI mobilisation at the project, and investigating the contractor's strategy to mobilise EI practices at the project. Through qualitative method, interviews are conducted with 15 contractors involved in the green development projects. The study found that the EI components within the contractor's work scope consist of product EI, process EI, and organisational EI. The conditions influencing EI mobilisation are the firm capability, project nature, and external enabler. The strategies adopted by the contractor to mobilise EI are human capitalisation, smart engagement, information dissemination, extending company policy to project implementation, strengthening documentation procedures, and technology optimisation. This research's findings could guide all parties on the matters of EI at the project, aside from enhancing the Malaysia's construction sector to thrive in the innovative practices while adopting sustainable construction.

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter provides an overview of the research topic and introduces key issues in this research. It establishes the primary context of this research, explains the research problem that led to the research questions and provides guidance to its aim and objectives. In addition, this section defines the scope of the research, describes the methodology this research is based on, and informs the direction for the contribution of this research. At the end of this chapter, the outline of this research is presented.

1.2 Research Background

The construction industry is one of the most economic-influencing sectors in the world. No country has grown to middle income without industrialising and urbanising, and none has grown to high income without vibrant cities. The rush to cities in developing countries seems chaotic, but it is necessary. The construction industry is the backbone of the country's economic progress due to its influence on every sector's role at all levels of the economy (Alaloul et al., 2021). This industry brings improvement in terms of enhancing the quality of life, expanding the rate of tourism, improving environmental sustainability, increasing money circulation, and providing job opportunities across the country (Alaloul & Musarat, 2020). With such lucrative benefits, it enhances the country’s focus on increasing its rate of construction development. Undeniably, there are abundant positive impacts from the construction industry. Nevertheless, the harmful impacts of the increasing rate of development activities are becoming apparent.

Mahat et al. (2019) explained that the whole supply chain of the construction processes has an inescapable impact on the environment, from the process of construction product manufacturing, transportation, storing of products, construction process, including at the end-user stage. At the project level precisely, Yao et al. (2007) stated that construction activities significantly contribute to environmental pollution. The activities such as earthworks, land clearing, disposal of construction waste (Yahaya & Abidin, 2020), logistics processes, utilisation of hazardous materials, and construction vibration (Jin, 2019) are all among the negative impacts of construction activities. Often, quality, cost and time are the three primary factors that have been emphasised to ensure project delivery success. In light of the environmental impact that the construction project activities have had on the surrounding area, in addition to the need to continue the construction project for economic contribution, environmental consideration should be integrated into the project's activities through creative measures.

The awareness that the environment and the economy are interdependent has stirred interest in finding ways for these two elements to co-exist. According to Hazarika and Zhang (2019), when discussing sustainable construction, a greater emphasis is often placed on energy emissions alone, which is effective, however, this approach is too narrow. Only confirming on emissions could imply that innovative efforts would only focus on producing energy more efficiently while ignoring the possibility of systematically reducing energy demand over a period of time through innovation (EIO, 2011a). Thus, to realise this need, the eco-innovation (EI) concept has been introduced.

Du Plessis (2002) affirms that EI was introduced to fundamentally address the complex problems between the construction and the environment in restoring the balance between the natural and built environments, as both realms are highly interconnected. The construction industry consists of 2 settings: firm and project levels. The EI adoption at the firm level is embedded within its business strategy, allowing for improvement in the product, process, and organisational structure (Isa & Abidin, 2021). While for the project level, the EI practices are embedded within the project's delivery practices in the form of product, process, and project development management. In both instances, the implementation of EI was meant to reduce the environmental burden while enhancing economic performance.

The majority of the construction industry's pollution occurred during project delivery. In addition, the nature of construction project complexity makes it more challenging to mitigate the adverse effects of this industry without new or more efficient technologies, processes, procedures, and methods. Since the EI concept offers means to boost efficiency and productivity in the industry while reducing the environmental impact (Reid & Miedzinski, 2008), its incorporation into construction project practices is promising. Therefore, the implementation of EI at the project level will be useful due to its capacity to enhance construction practitioners' procedures that must adhere to for project delivery.

The local governments are enforcing various regulations to foster a sense of environmental progress within the construction industry. Among them are the green building standards through the creation of local or adoption of international rating tools such as the Green Building Index (GBI), Malaysia Carbon Reduction and Environmental Sustainability (MyCREST), Manual Penarafan Hijau (pH JKR), and

Leadership in Energy and Environmental Design (LEED). These rating tools will provide the guidelines for green building development. Environmental Protection Agency (EPA, 2012) defined green building as the structure and usage of environmentally responsible and resource-efficient processes over the building life cycle. Prior research has demonstrated that green buildings can contribute significantly to environmental improvement by promoting energy efficiency, enriching ecological systems, and reduction of CO2 emissions. Through the pathway crafted by the intention of the green building practices arising in the market, adopting EI within green building development will provide systematic improvement in tackling the environmental issues caused by the project's activities. This is because the concept of EI itself is about finding new or better ways to attain higher functionality with lesser resources, new technological designs, and overall systematic changes in the construction process (EIO, 2011a).

Generally, the construction industry is fragmented in nature. Zooming into the project level, the construction project is perceived as a temporary organisation from permanent firms. The literature identified the characteristics of the temporary organisation as limited duration, unique outcomes, missing or blurred hierarchies, higher uncertainty and risks, and heterogeneous work teams (Bakker, 2010). With such industry characteristics, it is crucial to recognise and comprehend the role of construction team players "behind-the-scenes" of the project. This is because, according to Mathur et al. (2007), those who affect the project are also those who are involved in the delivery of the project, which determines the project's outcome. Thus, they are the main character accountable for this industry's impact on the increasing rate of environmental degradation.

From this view, attention should be brought towards the contractor's role in the construction project. The contractor should apply the concept of EI because this party is responsible for converting the design on paper into an actual structure (Powmya et al., 2017). However, despite this critical role in determining the success of construction project delivery, less research has been conducted on the contractor's influence on the long-term viability of the construction projects. Considering the importance of the contractor's role in a construction project, having tangible guidelines as the framework for the contractor to mobilise EI at the project level would benefit the client, consultants, and the other team players. Furthermore, previous research relating to EI has been concerning on the firm level, such as (Bamgbade et al., 2017; Isa & Abidin, 2021; Lee & Min, 2015; Triguero et al., 2013). In contrast, project-level implementation is equally important as it indicates the actual implementation of the EI.

Therefore, this research explores EI elements within the contractor's scope of work by investigating the underlying components and strategies to mobilise EI at construction project development. Attention will be given to the conditions that influence the EI mobilisation process. The outcomes of this study will provide a better understanding and overview of the influencing conditions to eco-innovate at construction projects, which is essential to ensure the construction project are handled in innovative and improved ways that take environmental protection into account, which encourage economic enhancement.

1.3 Research Problem

Scholars worldwide have repeatedly emphasized various environmental impacts caused by conventional construction practices (Duong et al., 2021; Enshassi et al., 2018; Thomas & Costa, 2017). The same sentiment has been raised in studies based on the Malaysia context (Bahaudin et al., 2017; Umar et al., 2021; Yusof et al., 2017). According to Mat Isa et al. (2019), continuing to deliver construction projects in their existing way will create more environmental problems. Hence, it is pertinent to speed up innovation adoption and direct innovative solutions toward ecological impact improvement. The Eco-Innovation Observatory (EIO, 2011) indicated that the construction industry needs a new direction to enable methods that promote the wellness of the environment and the flourishing of the economy. Hence, EI is viewed as a means of promoting environmental protection. Isa and Abidin (2021) explained that EI is a concept that integrates eco-consciousness within innovative development.

However, the problem's crux is that the construction industry tends to maintain its current practices and resists change (Ahn et al., 2013). It has been recognised that this industry is conservative in nature and reluctant to adopt new technology (Shapira & Rosenfeld, 2011). Therefore, it is unsurprising that many academics have branded the industry as slow to innovate compared to other sectors, such as manufacturing (Maghsoudi et al., 2016). This problem has been caused by the absence of a common language to define innovation, including the confusion of taxonomies and measurement of innovation within the construction sector (Davis et al., 2016). All these issues can be explained by the characteristics owned by this industry, which consist of high complexity and variability that each project possesses, risk-averse and capital intensity by nature due to its possible impact of the high cost and mistakes, and fragmented nature which can slow down the communication and collaboration for

innovative adoption (Silva & Warnakulasooriya, 2017). Hence, the "person-in-charge" of delivering the construction project, such as the contractor, struggles to discover and transfer innovation from one project to the next.

Within the Malaysian context, EI development has begun through the deployment of rating methods in addition to government-mandated rules and the promotion of awards and incentives to encourage construction practitioners to incorporate the green concept inside their projects. However, the results of these efforts are not yet apparent because most construction practitioners who had joined this endeavor come from large construction firms with sufficient capital only (Wethyavivorn et al., 2009). Mohamad Bohari et al., (2015) listed the factors impeding the advancement of EI in Malaysia's construction industry, including lack of guidelines, misunderstandings of green and sustainability ideas, and expensive budgets that the construction practitioners need to improve their practices. These are seen as the major obstacles that slow the progress of the construction industry to eco-innovate as a whole. This situation indicates that eco-innovating progress is still slow (Chegut et al., 2019). Therefore, a proper solution is needed to enhance the contractor's ability to adopt EI effectively within their means at the project.

Despite realising the importance of sustainability, it struggles to consistently implement eco-friendly practices due to a lack of dedicated frameworks tailored to contractors. EI can be implemented within this industry at both firm and project levels. EI at the firm level enhances its competitive advantage (Bamgbade et al., 2017), while at the project level, EI aids in increasing productivity, reducing environmental degradation throughout the construction progress, and reducing costs of the project (Yurdakul & Kazan, 2020). The study on EI in the construction industry has been

focused on the firm level by researchers such as Isa and Abidin (2021) and Ma et al. (2019). While at the project level, past studies on EI have focused on silo aspects such as greenhouse emissions, waste management, or energy efficiency (Arundel & Kemp, 2009; Ma & Hu, 2018), which might not be sufficient to explore how EI can be seamlessly integrated into the day-to-day operations of construction contractors.

In addition, the attention to EI has also been one-sided, looking at the firm or project levels. Scholars such as Hazarika and Zhang (2019) and Isa & Abidin (2021) indicate that EI at the firm level would have an impact on the project level as those involved in the projects are likely to apply their knowledge from the firm to the projects, wheres, no study has elaborated on how this connection being made. By understanding the implementation of EI at the firm level, the EI practices at the project level can be improved. This idea will directly instigate better actions for influencing more EI adoption for the projects. As such, these collective actions to eco-innovate can be translated into the Resource Mobilisation Theory (RMT), which concerns how organisations secure and deploy resources to achieve their goals (Jenkins, 1983).

Construction projects have dynamic systems in which many people are involved, and each can bring innovative solutions. Although the client is commonly considered the main driver for construction innovation (Loosemore & Richard, 2015), contractors and consultants alike can apply innovation within their scope of work to be more efficient in rendering services. At the construction site, however, the role of contractors is more prominent and thus strikes a better position to encourage the clients and consultants to choose more environmentally sound solutions (Powmya et al., 2019). Hence, this condition begs the question of how contractors can mobilise their actions to influence the project to implement EI? Furthermore, according to Tan et al.

(2011), a guiding framework can assist contractors in improving their EI practices. Thus, as mentioned in the preceding paragraph, RMT is used to practically create the framework by identifying the contractor's EI resources, recognising push and pull factors, and strategically using the resources to improve EI implementation.

To understand how contractors can influence EI within their projects, one must clearly understand what constitutes EI. In the Malaysian context, the current research on EI has been dominated by the manufacturing industry, in which the three components of EI, namely product, process, and organisational EI have been revealed in length (Singh, 2017). However, since such studies focus on manufacturing, the difference in job scope and work circumstances between manufacturing and construction may affect the appropriateness of those EI components for the construction industry (Isa & Abidin, 2021). While the premise of product, process, and organisational EI can be retained, each component's details may vary. Organisation for Economic Co-operation and Development (OECD, 1997) also stated that innovation between firm and project levels might differ due to different settings and the involvement of people from different backgrounds. Besides, due to the different taxonomies of innovation in the construction industry, the EI component is not clearly defined (Hunt & Gonzalez, 2018), especially within the contractor’s scope of work. Therefore, as the important party in the project development progress, it is necessary first to establish the contractor’s EI components before further actions can be forwarded to enhance the contractor’s EI implementation.

From the outside, the construction site can be seen as one of the most chaotic working places due to the sheer number of workers, the logistic movement within the site, the various plants and equipment, and the ongoing construction activities. The

management of the projects covers various aspects from safety, materials handling, workers' welfare, documentation management, and many more. The leading party responsible for managing the site is the main contractor (Powmya et al., 2017). With the continuous rise in technology and knowledge, many innovation solutions have been integrated into various aspects of site management and project handling. While many innovations aim to increase efficiency, environmental protection is still lacking. While the concept of EI aims to address this inadequacy, the movement toward embracing it is still unclear. As stated in the previous paragraph, past research on EI at construction projects are primarily in silo and focussing on certain technology.

Adopting EI at the construction site cannot be seen from one angle or silo view only. This is because many actors are involved in decision-making, which can have a bearing in deciding on the EI adoption. However, as a leading position during the construction phase, contractors can play a major role in EI adoption through their technological knowledge and previous experience, which can influence clients and contractors alike to pursue EI solutions. Nonetheless, the nature of the construction project and the involvement of various people in decision-making limits contractor's power in deciding on EI adoption (El-Kaoussi, 2018). While the contractor may have their own knowledge and capability to integrate EI for the projects, project requirements and clients' resistance may hinder such integration. As such, the contractor needs to understand the conditions that can influence their actions to mobilise EI practices for the project.

Introducing EI into construction firms and projects may disrupt the current project's practices. Although the practices will be beneficial, save time, and lead to more efficient and quality outcomes (Cai & Li, 2018) they may face some internal

resistance and hurdle during implementation. The formulation of strategies to coordinate resources and capabilities is vital for innovation performance. Since construction is one of the most dynamic and responsive sectors (Durdyev & Ismail, 2012), with the correct approach for EI mobilisation, this industry will be able to improve its practices according to the current developmental needs, which are environment and economic. Therefore, formulating the strategy that the contractor can adopt to mobilise EI within their capacity during the project development at the site will pave a clearer way for more effective EI adoption.

1.3.1 Research Questions

Based on the discussion above, three research questions have emerged as follows:

1. What are the components of EI within the capacity of the contractor as the builder for the construction project?
2. What are the conditions that can influence contractor to mobilise EI practices at the project?
3. How do the contractors strategize to mobilise EI effectively at the construction project?

1.4 Aim and Objectives of Research

This research aims to develop the contractor's eco-innovation mobilisation framework at construction projects. To achieve the aim, three objectives have been listed below:

1. To determine the components of EI at construction projects within the contractors' scope of work.

2. To examine the conditions that influence contractor in mobilising EI at construction projects.
3. To investigate the contractor's strategy in mobilising EI practices in construction project.

1.5 Scope of Research

The research focuses on the contractor's influence in mobilising EI during construction project development. Through this research, a framework for contractors' EI mobilisation will be proposed, which includes the elements of the components of EI, conditions influencing EI, and strategies for EI implementation. This study will be based on the Malaysian scope and focus on G7 Malaysian contractors located in Kuala Lumpur and Selangor. These two prime locations are chosen because they have the highest percentage of green buildings. Contractors involved with green development projects are chosen because this type of project has more environmental elements than conventional construction projects.

The Resource Mobilisation Theory is adapted into this framework to illustrate the connection of EI components with the influencing conditions and the strategies of EI mobilisation. This study's exploratory nature prompted the need to adopt a qualitative approach. The primary data collection will be based on phone and online interviews due to the Covid-19 pandemic.

1.6 Significance of Research

The significance of research can be seen from four aspects: the contractor, project, industry, and nation. Within the context of this study, the construction project is recognised as the temporary endeavour with a defined beginning and end,

undertaken by the contractor to create a unique result for the client. While for the term construction industry, it is the larger context that encompasses all construction-related activities involving architectural and engineering services such as contractors, suppliers, subcontractors, laborers, and equipment providers which form the market trend for the construction sector.

For the contractor, this research is significant because the constructed framework will allow the contractor to recognise the components of EI within their scope of work, aside from the conditions that will influence EI mobilisation and the strategies that contractor can adopt during their project implementation. Therefore, the contractor will be able to plan, control and manage these EI elements effectively. These conditions will allow the contractor to achieve the targeted benefits, especially for construction projects with high requirements such as projects with green rating tools.

As each project is unique and has its own requirements, an in-depth analysis relating to innovation and environment may offer light on the conditions that permit the implementation of EI at the project level. This research is significant to the project as it helps in guiding the aspect of environmental consideration to be assimilated with the element of innovation at the project. Thus, construction projects can be improved through this innovation that concerns environmental factors as the project progresses. This will directly enhance the overall outlook of the construction project toward better practices.

The construction industry's rate of innovation is frequently categorised as slow. Hence, at the industry level, this research is significant to improve the inefficiency of the construction industry’s innovation by providing a clearer view of the EI elements

within this sector. Through the provision of the framework and guidelines within this study, it can be used as the push factor in generating better output for the construction of green buildings. Therefore, the concept of EI, which integrates the elements of improvement with environmental consideration without ignoring the economic benefits, may change the mindset of construction practitioners to strategise their businesses towards more environmental concern.

In terms of the significance of this study at the nation level, this research will answer the call for Malaysia's plan in the Sustainable Development Goals achievement by outlining the framework for the construction industry to move away from the comfort of conventional practices. In addition, this research is essential for addressing the sustainability component that has been highlighted as one of the core values in the Construction 4.0 Strategic Plan (2021 - 2025) to ensure that the Malaysian construction sector is prepared to embark into the competitive technological advancement that is happening worldwide.

1.7 Brief of Research Methodology

This research adopted the qualitative method as it requires an in-depth understanding of how the contractor mobilises EI and what would influence EI mobilisation for the contractor at construction projects. The exploratory nature of the qualitative approach enables the researcher to obtain deeper and enhanced knowledge on the topic. This research employed semi-structured interview as it allows for better generation of information due to its flexibility and is essential to gather appropriate information as the interview unfolded, given that there is relatively little written concerning this topic (Roddis, 2018) especially relating to the EI in the service sector such as construction industry. The in-depth interview was conducted with 15

respondents who are the main contractors that have been involved in construction projects with green rating tools. All the respondents are from grade G7 contractor firms; most of the projects were located in the Klang Valley area, and 1 project was in Pahang. The data obtained from the interviews were analysed using Atlas.ti software. The methodology of this research will be explained further in Chapter 3.

1.8 Guide to the Thesis

This thesis is structured into five chapters according to the format provided by Universiti Sains Malaysia. Each chapter is summarized below.

Chapter 1 introduced the research by providing the background of the research, the problem statement, the aim and objectives, the scope and a brief methodology employed for the research. This chapter ends by explaining the overall structure of the thesis.

Chapter 2 provides the literature review on EI within construction in general before highlighting the EI components within the contractor's scope of work. This chapter explained the definition of EI and its concept before delving into a lengthy discussion on the strategy for the contractor to influence EI mobilisation at the project level. This chapter provides a background understanding of the issue from the perspective of various past research.

Chapter 3 presents the research methodology applied in this study. The aspect such as the design of this study, data collection method, and type of analysis used are briefly explained in this section.

Chapter 4 elaborates on the interview findings and results from the data analysis conducted. The overall discussion of the findings is also included in this chapter.

Chapter 5 concludes the research which includes the achievement of the aim and objectives, limitations of the study, and recommendations for future studies.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter lays the groundwork related to the topic of this study. It consists of several sub-chapters which focus on the relation between the construction industry and innovation, the construction activities' impact on the environment, and the innovation progress in this industry. The aspects of EI components, conditions influencing EI mobilisation, and the contractor's strategy to mobilise EI at the project were thoroughly reviewed. Finally, the conceptual framework which adopts Resource Mobilisation Theory (RMT) is proposed.

2.2 Construction Industry, Environment, and Innovation

2.2.1 Construction Industry and Its Impact on the Environment

The construction industry is undeniably one of the most critical contributors to countries' financial success. Quoted by Dlamini (2012), *"an industry sector this big could not but have an impact on the economy"*. The construction sector accounts for 10% of the Gross Domestic Product (GDP) and employs about 7% of the workforce in the European Union (EU) which is one of the leading markets to boost competitiveness and promote sustainability (Braulio-Gonzalo & Bovea, 2020). By countries according to Ajayi et al. (2016), the construction industry in the United Kingdom (UK) accounted for 8% of its GDP and contributed to an annual value of over £100 billion. While in the United States (US), the construction industry is valued at over $1 trillion, which created critical infrastructures to support other industries (Chong et al., 2009) and in China, the National Bureau of Statistics of China (NBSC, 2022) reported that the contribution of the construction industry to the total GDP was close to RMB20 trillion.

Focusing on the Malaysia's perspective, the Construction Industry Development Board (CIDB) reported that the Malaysian construction industry had played vital roles in the country's development by assisting other sectors in thriving while contributing 3% to 7% of GDP over the last decade (CIDB, 2016). Thus, the construction sector is considered one of the contributors to Malaysia's economic growth and financial stability. Aside from the GDP's contribution, Alaloul et al. (2021) noted that the construction industry helps Malaysia to accomplish social development, industrialisation, freight transportation, social and sustainable development, and urbanisation.

However, construction-related developments have detrimental environmental implications (Du et al., 2022). Align with the increasing pace of economic development, this condition indirectly forces the generation of heavy burdens on the environment and society (Gan et al., 2015). According to Akadiri and Fadiya (2013), considerable evidence has emerged as the consequences of uncontrolled construction activities. Throughout the construction activities, various physical activities have direct and irreversible environmental consequences (Yahaya & Abidin, 2015), which cause numerous environmental issues.

Due to uncontrolled construction activities, environmental degradation, and the increase of Greenhouse Gas (GHG) emissions occurred. Furthermore, from the data provided by Zolfagharian et al. (2012), construction activities influence around 67.5% and 21% of Malaysia's ecology and natural resources, respectively. Issues of deforestation, landslide, soil erosion, mud flows, flood, and water pollution in Malaysia are reported due to inefficient and misconduct of the on-site construction activities (Abidin, 2010). These had caused chaotic disruption of existing ecology, flora and fauna habitats, human settlements, and historical features.

Malaysia has recorded increasing numbers for the construction of major infrastructure projects, commercial buildings, and housing programmes that lead to significant construction waste. Kupusamy et al. (2019) reported that construction and demolition (C&D) waste constitutes around 20% to 30% of the total landfill waste in Malaysia. The types of waste from these construction activities are wood, metals, and concrete, including mixed waste. The source that worsens the condition is that poor regulations and guidelines govern this C&D waste generation in Malaysia.

Another negative impact of this construction industry is the production of excessive carbon emissions. Almost a decade ago, scholars had already ranked the construction sector as the primary source of carbon emissions. According to the International Energy Agency (IEA, 2021), the combination of both structure of the buildings and the progress of buildings construction sectors are responsible for over one-third of global final energy consumption and nearly 40% of the total direct and indirect carbon dioxide (CO_2) emissions. This situation is still persistently happening, as reported by the Global Status Report 2019 by International Energy Agency (IEA, 2019), the construction sector accounted for 36% of final energy use and 39% of energy and process-related CO_2 emissions in 2018. This condition proved that as years passed, the problem of carbon emissions is still a significant issue caused by the construction sector.

With all the negative consequences of the traditional construction practices listed above, researchers including Yusof et al. (2017) have classified this sector as an environmental-unfriendly industry. At this point, it is obvious that the one factor that this industry should consider is the fusion of the environmental consideration aspects within each construction practice. Nevertheless, the construction development must be continued for the nation's economic prosperity and to meet the requirements of its population. Thus, improvement, also

known as innovation, in terms of construction practices is required to reconcile the environmental concerns with the current construction practices.

2.2.2 Innovation Progress in Construction Industry

Innovation is defined by Schumpeter (1983) as the commercial or industrial application of something new such as a new product, new process, new method of production, new market or source of supply, and new form of commercial, business, or financial organisation. In the construction industry context, innovation can be explained as the concept of "newness", whether the organisation is pioneering or only adopting the new elements, as long as these innovative actions benefit the organisation that implements those new practices (Tatum, 1987). Generally, among the notable innovation that was acknowledged globally are known as the industrial revolution.

According to Maskuriy et al. (2019), during the first industrial revolution, the heavy mechanical industry underwent exponential growth, creating numerous new building products. This improvement included the invention of glass, cast iron, and steel by engineers and architects for use in the construction of buildings that, at the time, no one could have thought could exist in terms of architectural usefulness (Sreekanth, 2011).

While for the second industrial revolution, it enabled mass production which caused to replacing the manual labour works with electric energy that drove the manufacturing industry to produce a mass number of steel, electricity, telegraphs, and railroads (Mokyr, 1999). This revolution drove the construction industry in terms of innovation in architectural design and lightening vertical space (Gildow, 2012) alongside new prefabrication technology and the beginning of computer-aided design (CAD) (Bethany, 2017). This innovation provided numerous unforeseen opportunities that are still being used today.

In continuation, the third industrial revolution started the information technology revolution which were informatisation based on computers and the internet (Mahmud et al., 2018). This industrial revolution established a new relationship between architecture and technology, which posed a challenge to the manufacturing industry (Kolarevic, 2001). This improvement indicated the starting of 3D computer-aided design software usage (Naboni & Paoletti, 2015). As a result, complex constructed geometries buildings were designed using computer numerically controlled (CNC) fabrication processes (Kolarevic, 2001).

Today, along with the highly competitive market, the recent Industrial Revolution 4.0 is still a relatively new topic. Nevertheless, it has a significant impact on the construction industry. The Industrial Revolution 4.0 refers to the Internet of Things (IoT) and the Internet of Services (IoS) integrated with the manufacturing environment in which all industrial businesses around the world connect and control their machinery, factories, and warehousing facilities intelligently through cyber-physical systems by sharing information that triggers actions (Gilchrist, 2016). With the availability of digital data and online digital access, this revolution has challenged the industry by demonstrating the construction digitisation potential that can be used to automatically gather and process electronic data discrete tasks into the value chain (Alaloul et al., 2018). Basically, the ideas of digitization and digitalization have been fused into the construction industry's practices which opened doors for construction practitioners to adopt the improved technologies.

In the context of the Malaysian construction industry, the construction sector has become more competitive as the multinational enterprises expanded their operations (Abdul-Aziz & Wong, 2010) which has been facilitated by international trading agreements, as well as foreign aid and loans targeted at infrastructure construction provided by the Ministry of International Trade and Industry (MITI, 2020). According to Chang et al. (2016), the Malaysian

construction industry is characterised by two sources of innovation. The first is that the innovative idea originated from the construction company, but it was adapted from technologies utilised by foreign companies, and the second is that the construction company bought the original technology, then adapted and customised it to the company's processes or the market needs. Chang et al. (2016) provided the example of innovation in Malaysia such as the Stormwater Management and Road Tunnel (SMART), also known as SMART Tunnel, usage of Precast Shell Beam and Reinforced Slab Strip, the Do-It-Yourself house, and the application of 5D systems.

Hence, it is apparent that the construction industry's progress underwent various innovations to meet the needs of society and the organisational demand to survive in the global market. This situation showcased that the construction industry is prone to implement and adapt the innovation needed in the market. The aspect of sustainability and innovation must be assimilated together so that the construction progress will be both sustainable and innovative. This action is crucial to ensure the balance between the continuation of economic activities while at the same time, ensuring the wellness of the environmental condition. Therefore, the innovative aspect of construction practices needs to be bridged with the need for environmental concern.

2.3 Innovation in Construction Industry

The concept of innovation is not new because it has been applied and became a foundation for organisational development and growth in the past centuries. Moreover, according to Polder et al. (2010), innovation is regarded as a key driver of productivity growth. The introduction of new goods and services, as well as novelties in methods of production and non-technological aspects such as management practices and marketing, enable businesses to

increase their productivity (Polder et al., 2010). This section explored the understanding of innovation in the construction industry.

2.3.1 Defining Innovation

Innovation is a term that is derived from Latin word, “innovare”, that brings the meaning “to make something new” (Salah & Rahim, 2019). As stated by Fadhilah and Ramayah (2012), innovation amplifies the concept of newness. While for Kemp and Foxon (2007), innovation is commonly defined as a novelty that leads to market value creation. Interestingly, Bessant (2013) classified innovation into two categories; the first is little incremental improvements that is to “doing what we do but do it better” and second, the radical improvement which is the implementation of action that is completely new to the world. This showed that “innovation” would happen whether the organisation creates or only adopts improved practices into their operations. The Oslo-Manual by Organisation for Economic Cooperation and Development (OECD, 1997) described innovation as technical or organisational in nature and had classified these innovations into a few categories such as product, process, and organisational innovation.

Even if the standard definition of innovation is interpreted differently and often debated vigorously within the construction industry, the definition supplied by Slaughter (1998) is generally recognised by other scholars. Slaughter (1998) defined innovation as the actual use of a nontrivial change and improvement in the process, product, or system that is novel to the institution developing the change. Aligned with the definition of innovation from OECD (1997), Lim and Peltner (2011) recorded two distinct forms of innovation in the construction industry: technology and management innovation. According to Isa and Abidin (2021), technological innovation refers to adopting technology in products, services, and processes engaged in construction practices. While for the latter, Isa and Abidin (2021) added that

management innovation involves changing the internal organisational structure such as the implementation of management systems, partnering and augmenting the supply chain for the organisation, enhancing human resource development, and introducing the improved policy, procedure and organisational approaches that can lead the organisation's operation towards better practices.

From the above definitions supplied by the scholars, it can be concluded that innovation is the process of making changes and improving one's situation toward better operational practices. However, according to Szutowski (2021), the up-to-date issue of innovation in the service industry attracted less scientific taught than that of innovation in the manufacturing sector. The service industry involves the construction sector as well.

Within the construction industry, researchers mentioned that due to the low rate of productivity in comparison with other industries, the construction sector is frequently criticised. One of the primary causes of the problem is that this industry lacks innovation (Orstavik et al. 2015). Therefore, to improve this situation, reflecting on the definition of innovation supplied by Bessant (2013) which categorised innovation in construction into technological and organisational innovation, these two aspects should be stressed as they can raise and expedite the construction industry's position in terms of innovativeness.

On the other hand, researchers such as (Davis et al., 2016; Xue et al., 2014) stated that most of the construction innovation is co-develop at the project level. Therefore, the components of innovation, specifically at the project level, should be explored to accelerate the innovation process for the construction industry. To begin with, it is critical to comprehend the types of innovation in the construction industry.

Innovation is the act of developing and combining ideas to bridge the current accomplishment with past experiences to solve potential future challenges (Stenberg, 2016). It