INVESTIGATING THE DRIVERS AND BARRIERS OF CONSTRUCTION INNOVATION IN MALAYSIA

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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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ABSTRACT

The construction industry is a cornerstone of economic development, yet it remains comparatively slow in adopting innovation relative to other sectors like manufacturing and information technology, especially in Malaysia. This study investigates the drivers, barriers, and underlying factors influencing construction innovation in the Malaysian construction industry. Motivated by the growing importance of innovation for competitiveness and sustainability, the research combines an extensive literature review with a structured questionnaire survey of 150 practitioners, including developers, consultants, and contractors in the Klang Valley region. Rigorous statistical analyses were applied to ensure the robustness of findings, including reliability testing, normality assessment, and factor analysis. The results identified technology push, environment and sustainability, technological capability, strategic alliances, and subsidies as the most critical drivers, reflecting both global trends and local industry needs. Conversely, lack of financial resources, operational resource gap, lack of technical capabilities, lack of incentives, and inappropriate legislation emerged as the most significant barriers. The factor analysis further revealed six latent drivers and five latent barriers, illustrating that innovation is influenced by institutional, organisational, market, and behavioural dynamics. Respondents also expressed cautious optimism about the future, acknowledging the importance of innovation for competitiveness while noting persistent concerns over preparedness and resource allocation. The study provides important implications for practice, policy, and academia in Malaysia, as well as for other developing countries facing similar challenges or seeking to develop a more future-ready construction industry. Overall, the findings underscore the need for coordinated strategies to overcome barriers and transform innovation awareness into sustained industry advancement.

Keywords: construction industry; construction innovation; drivers; barriers; Malaysia

Subject Area: HD9715-9717.5 Construction industry

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LIST OF SYMBOLS / ABBREVIATIONS

α	Cronbach's alpha
AEC	Architecture, Engineering, and Construction
AECO	Architecture, Engineering, Construction, and Operations
BIM	Building Information Modeling
CIDB	Construction Industry Development Board
CSR	corporate social responsibility
DfMA	Design for Manufacturing and Assembly
GBI	Green Building Index
GDP	Gross Domestic Product
ICT	Information and Communication Technology
IGO	intergovernmental organisation
IoT	Internet of Things
MEP	Mechanical, Electrical, and Plumbing
MMC	modern methods of construction
R&D	Research and Development
SAM	Semi-Automated Mason
SME	small and medium-sized enterprises
VFE	virtual field experience
VRGS	Virtual Reality Geological Studio

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

The construction sector is a fundamental pillar of economic development that significantly contributes to the economies of nations worldwide (Aouad, Ozorhon and Abbott, 2010; Azman *et al.*, 2024). Malaysia is likewise impacted by this dynamic industry. Since achieving independence, Malaysia has consistently recognised the construction industry's pivotal role in fostering economic growth (Kamal *et al.*, 2012). The economic contribution of the construction industry can be analysed through its impact on the Malaysian Gross Domestic Product (GDP), employment levels, and its extensive interconnections with other sectors. According to the Department of Statistics Malaysia (2025b), the annual nominal GDP contribution of the construction sector stands at RM 65,949 million. Moreover, recent economic data indicates a robust recovery within the industry, with a notable growth rate of 20.7% recorded in the fourth quarter of 2024. Despite this resurgence, the sector's contribution to the national GDP remains relatively modest, constituting only 3.62% in 2023, as detailed in Table 1.1.

Table 1.1: GDP Contribution by Construction Sector, adapted from Department of Statistics Malaysia (2025b).

Annual Nominal GDP 2023	**RM million**
All sectors	1,822,904.40
By construction sector	65,949.00
% by construction sector	3.62%

While the construction sector's direct economic contribution appears limited, it is still considered one of the main sectors of the Malaysian economy as its role extends far beyond these figures (Dehdasht *et al.*, 2022). The construction industry serves as a vital engine for economic growth by creating both backward and forward linkages. It plays an essential role in providing infrastructure and facilities that enable economic activities across multiple sectors, including manufacturing, services, and trade (Ali, Sabir and Muhammad, 2019). At the same time, it is a substantial consumer of goods and services from various industries, creating demand for raw materials such as cement, steel, timber, and glass, among others. Through backwards linkages, the construction sector stimulates growth in supplier industries by procuring substantial quantities of building materials and components (Pheng and Hou, 2019). These materials are often sourced from relatively low-cost, labour-intensive domestic industries, particularly those involved in basic manufacturing such as cement and steel production. This interdependence amplifies the sector's multiplier effect, fostering industrial growth and employment opportunities (Pheng and Hou, 2019). Notably, the manufacturing sector contributed substantially to the GDP in 2023, reaching RM 419,548.00 million (Department of Statistics Malaysia, 2025b). This figure represents 23.02% of the total GDP in the year 2023.

According to Global Construction Perspectives and Oxford (2015), the global construction market is expected to grow by 80% by 2030 compared to its size in 2015 (Gong and Wang, 2022). Consequently, the construction industry must remain dynamic to adapt to the ongoing changes in the world, as client needs and demands will not remain constant. Additionally, advancements in construction materials and techniques will greatly impact the design, construction, and maintenance of the built environment (Aouad, Ozorhon and Abbott, 2010). Innovation serves as a crucial catalyst for the transformation and modernisation of the construction industry. According to OECD (2005) and EC (2010), innovation is recognised for its contribution to stimulating national economic growth, boosting competitiveness, and elevating living standards (Aouad, Ozorhon and Abbott, 2010). In particular, the shift towards "sustainable construction" has garnered significant attention as the industry transitions from traditional practices towards environmentally responsible development models (Plessis, 2007). The Construction 4.0 Strategic Plan (C4.0) is an initiative by the Construction Industry Development Board (CIDB) Malaysia to drive the adoption of digital technologies and advanced construction methods in the Malaysian construction sector (CIDB, 2023). It aligns with Industry 4.0 principles, aiming to enhance productivity, efficiency, and sustainability.

Malaysia must strategically guarantee that the development of new technologies is sufficient to promote a sustainable and inclusive economy (Law, Sarmidi and Goh, 2020). However, the nation faces challenges in the widespread adoption and integration of emerging technologies, such as the latest Internet of Things (IoT) (Ibrahim, Esa and Rahman, 2021). Therefore, understanding the key drivers and barriers to construction innovation is imperative for nurturing a dynamic, resilient, and sustainable industry. As Malaysia seeks to align its construction sector with global economic and environmental objectives, a strategic focus on technological innovation, sustainable practices, and digital transformation will be essential.

1.2 Problem Statement

The construction industry is a major consumer of energy, accounting for 1/3 of global energy use, where approximately 60% of energy consumption is related to the construction sector (Jing and Kong, 2016). As shown in Figure 1.1, the energy sector is the largest source of greenhouse gas emissions globally, contributing to a substantial 75.7%. Construction activities are intrinsically linked to several components within the energy sector's greenhouse gas emissions profile, notably manufacturing and construction processes, which account for 12.7%, as well as building operations, contributing 6.6%. Additionally, construction is indirectly associated with other components such as electricity and heat production (29.7%) and transportation (13.7%), given its reliance on energy consumption and material logistics (Ge, Friedrich and Vigna, 2024). According to Sepehrdoust, Javanmard and Rasuli (2022), an increase in construction activities is expected to lead to a rise in environmental pollution. The production of common construction materials like concrete, steel and aluminium is projected to increase carbon emissions to dangerous levels if urgent action is not taken (United Nations Environment Programme Yale Center for Ecosystems + Architecture, 2023).

Traditional construction methods not only have a significant environmental impact but also face challenges in terms of project performance. While these methods have been the norm for decades, they come with major limitations such as fragmentation and inefficiency which contribute to underperformance (Yahya and Ismail, 2011). Okereke, Ihekweme and Adegboyega (2022) found that project delivery through the traditional procurement system has the most detrimental impact on project time parameters, aside from cost and quality. Their research revealed that poor performance in these areas is often attributed to factors such as rework, inadequate initial planning or unrealistic scheduling, ineffective communication among project participants, a lack of skilled personnel, insufficient training for existing staff, and issues related to design and documentation. Okereke, Ihekweme and Adegboyega (2022) stated that if progress toward modern and advanced procurement systems does not occur, project performance in the sector will continue to decline.

Traditional methods have also been criticised for their limited efficiency in innovation despite being a cornerstone of economic activity compared to other industries (Aouad, Ozorhon and Abbott, 2010; Wang, Xu and Liu, 2023). The construction sector has remained relatively stable in terms of transformative innovations over the past few decades, especially when contrasted with other industries that have experienced significant disruptions (ESCO, 2021). Previous studies predominantly concluded that the industry is slow to innovate, with construction innovation being rare (Gambatese and Hallowell, 2011; Davis *et al.*, 2016; Adekunle *et al.*, 2024). Nevertheless, innovation is essential for addressing the environmental and operational challenges faced by the construction industry (Deng and Noorliza, 2023; Dang *et al.*, 2024). Recent studies have indicated that alternative methods, such as prefabricated and 3D-printed buildings, can significantly reduce carbon emissions compared to traditional construction techniques (Zhao, Liu and Yu, 2023). Research by Rossi et al. (2024) discovered that greenhouse gas (GHG) emissions from 3D-printed houses are lower than those from conventionally built ones, as shown in Figure 1.2. However, despite these promising innovations, the industry remains slow to adopt new technologies and practices (Isa and Abidin, 2021). Challenges such as uneven adoption rates and cultural inertia persist, even with advancements in adopting innovative sustainable practices (Mitchell, 2023; Norris, 2023). For example, the adoption of innovative technologies like Building Information Modelling (BIM) in Malaysia has been slow compared to other countries (Ali, 2024).

Numerous existing studies have highlighted the importance of innovation in construction to improve current performance levels (Akunyumu *et al.*, 2021; Ahmad, 2023; Saari *et al.*, 2024). Nonetheless, there remains a lack of research concerning the specific drivers and barriers to innovation in regional contexts, particularly in Malaysia. Identifying these factors is essential to bridging the research gap and providing targeted solutions to address the issues directly. Therefore, this study seeks to fill this void by investigating the experiences of Malaysian construction stakeholders with recent innovations and identifying the drivers and barriers specific to this regional context. Such focused research is essential to bridge existing knowledge gaps and inform contextually relevant solutions that can accelerate innovation adoption and improve sustainability and performance within Malaysia's construction industry.

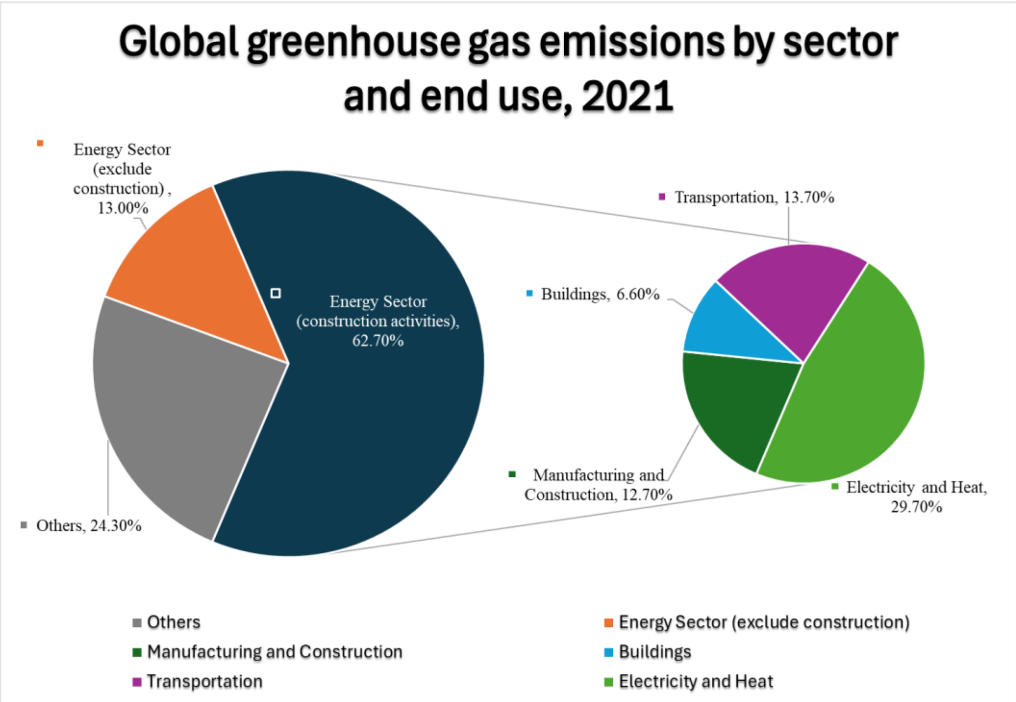

Figure 1.1: Global Greenhouse Gas Emissions by Sector and End Use, adapted from Ge, Friedrich and Vigna (2024).

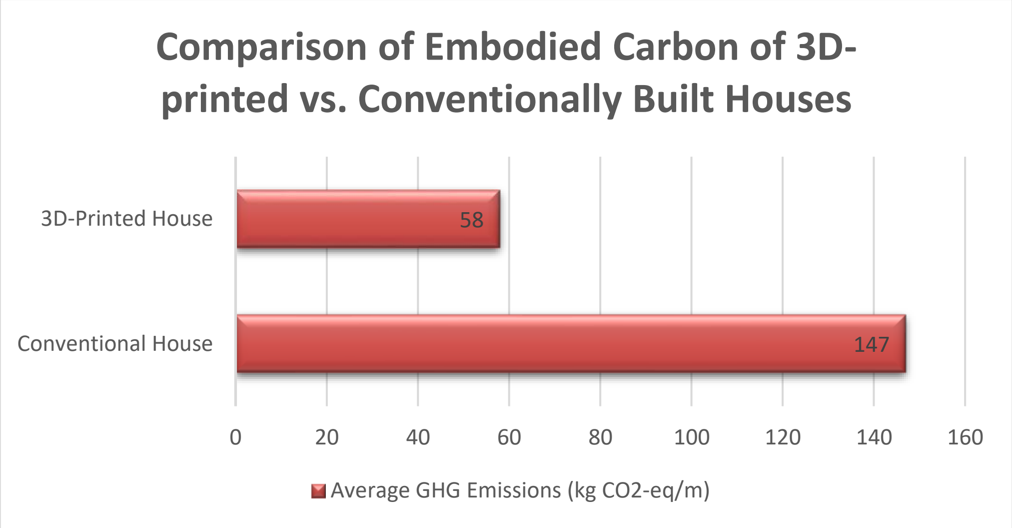

Figure 1.2: Comparison of Embodied Carbon of 3D-printed vs. Conventionally Built Houses, adapted from Rossi et al. (2024).

1.3 Research Aim

This study aims to examine the key drivers and barriers influencing innovation and its underlying factors in Malaysia's construction industry.

1.4 Research Objectives

The research objectives outlined below are created to achieve the previously mentioned research aim:

(i) To examine the key drivers that promote innovation in Malaysia's construction industry.

(ii) To evaluate the barriers that hinder innovation adoption within the industry.

(iii) To uncover the underlying factors that influence the success and challenges of innovation implementation in Malaysia's construction industry.

1.5 Research Question

The research questions this research aims to address are as follows:

(i) What are the key drivers that promote innovation in Malaysia's construction industry?

(ii) What barriers hinder the adoption of innovation within Malaysia’s construction industry?

(iii) What are the underlying factors that influence the success and challenges of innovation implementation in Malaysia’s construction industry?

1.6 Research Methodology

The scope of this research focused on drivers and barriers to construction innovation in Malaysia. The study utilises a quantitative research method by sending out questionnaires to individuals working in the construction field. The focus group for this research consists of professionals who are currently involved in Malaysia's construction industry, which includes clients, consultants, and contractors. The determination of an appropriate sample size is achieved through a power analysis aiming to secure statistical significance in the study's findings. The analysis methods adopted in this research include Cronbach’s Alpha Reliability Test, ranking analysis of variables, Kruskal-Wallis Test, and factor analysis.

1.7 Limitations of the Study

While this study will provide valuable insights, it's important to note that people's opinions may be subjective, and the results may only apply to the Malaysian construction industry. Overall, this research will help us understand how to promote innovation in the construction sector.

1.8 Contribution of the Study

This study aims to delve deeply into the experiences of construction stakeholders in Malaysia, examining their interactions with recent innovations. Moreover, it aims to identify the specific drivers and barriers unique to the Malaysian context, offering a thorough insight into the challenges and opportunities for innovation within the industry. The findings also carry implications for other developing countries facing similar challenges, providing guidance for creating a more resilient, competitive, and future-ready construction industry.

1.9 Report Outline

The report is divided into five distinct chapters, each systematically addressing the research objectives and offering a thorough analysis of the study topic. The structure of the report is organised as follows:

Chapter 1: Introduction

This chapter acts as the foundational section of the report, providing a summary of its content and range. It highlights the construction industry's crucial position in the national economy and stresses the need to promote innovation in this sector. Essential elements encompass the problem statement, research aims and objectives, research methodology, limitations and contributions of the study, and an outline of the chapter.

Chapter 2: Literature Review

This chapter begins by defining essential terms such as "innovation," "drivers," and "barriers." It then provides a critical review of recent innovations within Malaysia's construction industry. Moving on, it identifies and analyses the primary drivers and barriers to innovation by synthesising existing literature. Comparative insights from various researchers are presented to offer a nuanced understanding of these factors.

Chapter 3: Research Methodology

This chapter details the research framework, focusing on quantitative methods employed throughout the study. It includes a description of research types and processes, sampling design and data collection techniques, and a comprehensive explanation of data analysis methods. The chapter also highlights how questionnaires were designed and distributed to targeted respondents, ensuring robust data collection aligned with the research objectives.

Chapter 4: Results and Discussion

This chapter presents a thorough analysis and interpretation of the collected data. It examines responses from participants to derive meaningful insights related to the research topic. The findings are discussed in relation to the study's objectives, providing a deeper understanding of innovation drivers and barriers within Malaysia's construction sector.

Chapter 5: Conclusion and Recommendations

The concluding chapter integrates the main results of the study, highlighting their significance for enhancing awareness of construction innovations in Malaysia. It also outlines the limitations faced during the research and suggests recommendations for future research. These recommendations are designed to fill knowledge gaps and encourage further progress in construction innovation.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents a critical review of the literature pertaining to the research topic. The sources analysed in this chapter include journals, research papers, academic books, organisational reports, and conference proceedings. The objective of this chapter is to provide a comprehensive overview of prior research on innovation within the construction industry, while also delivering a critical assessment of the literature. Furthermore, it establishes a theoretical framework to guide this research endeavour.

2.2 Definitions

2.2.1 Innovation

Innovation, as defined by OECD/Eurostat (2018), refers to the implementation of new or significantly improved products, processes, marketing methods, or organisational practices in business operations. This comprehensive definition underscores a crucial point: for innovations to truly be recognised as such, they must be actively applied and implemented in real-world contexts. Similarly, Adegbesan and Ricart (2007) expanded this concept to include innovations in areas like marketing, pricing, sales methods, and management practices, emphasising that innovation is not limited to technical aspects. Supporting this view, Gajendran et al. (2014) categorised innovation outcomes into product/service innovation, process/design innovation, market-based innovation, supply-based innovation, organisational innovation, and business model innovation. They argued that there is no longer a need to distinguish between technical and managerial innovations since both are interlinked.

Kogabayev and Maziliauskas (2017) underscored innovation as a core driver of economic development. They noted that it improves productivity by reducing costs, enhancing quality, and saving time. Meanwhile, Aouad, Ozorhon and Abbott (2010) emphasised the context-sensitive nature of innovation. They argued that its benefits are realised only through a comprehensive understanding of the entire process, namely knowledge acquisition, transformation, and diffusion.

In the construction industry specifically, Dikmen, Birgonul and Artuk (2005) proposed a framework defining construction innovation as systematic operational change influenced by goals, environmental drivers, strategies, and organisational factors. Similarly, Orstavik, Dainty and Abbott (2015) defined construction innovation as humanly created changes in established approaches to value creation. This includes introducing new ideas or methods that transform how value is generated through products, processes, or business models. Construction innovation extends beyond tangible outputs like materials or structures to intangible aspects such as workflows and stakeholder collaboration.

Finally, Maier (2018) highlighted the strategic importance of innovation for organisations operating in competitive environments. Innovation enables firms to adapt to changing needs while maintaining a competitive edge. In construction, specifically, it ensures project quality and long-term survival in a dynamic market. Table 2.1 summarises the definitions of innovation by various researchers.

Table 2.1: Definitions of innovation by various researchers.

Term	Definition	Citations
Innovation	Implementation of a new/significantly improved product, process, marketing method, or organisational method.	OECD/Eurostat (2005, p. 46)
	Core driver of economic development; reduces costs, improves product quality, and accelerates processes.	Kogabayev and Maziliauskas (2017, p. 59)
	Context-sensitive; requires understanding knowledge acquisition, transformation, and diffusion.	Aouad, Ozorhon and Abbott (2010, p. 375)

Table 2.1 (Continued)

	Systematic model involving goals, environmental factors, strategies, and organisational factors to operationalise change.	Dikmen, Birgonul and Artuk (2005, p. 82)
Construction Innovation	Humanly created changes in value creation via new ideas, methods, or technologies. Must be lasting and diffused across stakeholders.	Orstavik, Dainty and Abbott (2015, p. 4)
	Strategy for organisational survival in competitive environments; adapts to changing needs and markets.	Maier (2018, p. 157)

2.2.2 Drivers

From a broad perspective, Damanpour and Schneider (2009) defined drivers of innovation as factors that generate the fundamental impetus for adopting and implementing innovations. These drivers act as the primary motivators for organisations to pursue innovative activities, whether to address external pressures such as market competition or internal needs like improving efficiency and reducing costs. They emphasise that these factors provide the essential momentum required for organisations to innovate, making them critical to the innovation process.

Drivers of innovation refer to the primary reasons, motivations, or factors that create the impetus for organisations or individuals to adopt and implement innovative ideas, processes, or products. According to Ozorhon, Oral and Demirkesen (2016), drivers represent the core motivations for project parties to invest in innovation. These motivations often stem from a need to address specific challenges or opportunities within a project or organisation. Ozorhon (2013) also noted that drivers are the external and internal forces that push organisations toward innovation to remain relevant and competitive.

In summary, drivers of innovation are context-sensitive factors that motivate organisations to innovate. They encompass a wide range of influences, including client demands, market competition, technological progress, regulatory frameworks, sustainability goals, and organisational performance needs. These drivers serve as the foundation for fostering creativity and change within businesses and industries. Table 2.2 below summarises the definitions of drivers by various researchers.

Table 2.2: Definitions of drivers by various researchers.

Definitions	Citations
Factors that generate the fundamental impetus for adopting and implementing innovations.	Damanpour and Schneider (2009, p. 496)
External and internal forces that push organisations toward innovation to remain relevant and competitive	Ozorhon (2013, p. 456)
Primary reasons for project parties to invest in innovation, often stem from challenges or opportunities.	Ozorhon, Oral and Demirkesen (2016, p. 2)

2.2.3 Barriers

Barriers to innovation are the obstacles, challenges, or constraints that hinder organisations from adopting, implementing, or successfully carrying out innovative activities. These barriers can arise at various stages of the innovation process and may prevent firms from investing in innovation or achieving desired outcomes. According to Ozorhon, Oral and Demirkesen (2016), barriers consist of problems and challenges that stop companies from pursuing innovation initiatives. These challenges can deter organisations from allocating resources or engaging in innovative practices. From a broader perspective, D'Este et al. (2012) describe barriers as obstacles firms face when undertaking innovative activities. These barriers may include cost-related issues (e.g., insufficient financial resources), knowledge-related limitations (e.g., lack of expertise or information), and market-related constraints (e.g., inability to bring innovations to market). The OECD/Eurostat (2018) identifies barriers as elements that stop non-innovative companies from participating in innovation or obstruct innovation-active firms from launching certain forms of innovation. They also added that challenges to innovation raise expenses or lead to technical issues, but they are normally resolvable.

In summary, barriers to innovation encompass a wide range of challenges that impede the innovation process. These include financial constraints, organisational resistance to change, lack of collaboration, regulatory hurdles, and market limitations. Addressing these barriers is essential for fostering an environment conducive to creativity and progress. Table 2.3 summarises the definitions of barriers by various researchers.

Table 2.3: Definitions of barriers by various researchers.

Definitions	Citations
Problems and challenges that stop companies from pursuing innovation initiatives.	Ozorhon, Oral and Demirkesen (2016, p. 2)
Obstacles that firms face in undertaking innovation activity.	D'Este et al. (2012, p. 486)
Factors that block non-innovative firms from starting innovation efforts or limit firms already engaged in innovation from adopting new types of innovations.	OECD/Eurostat (2018, p. 160)

2.3 Case Studies: Construction Innovations in Malaysia

The Malaysian construction industry demonstrates a growing but uneven adoption of technological innovations across various project phases. Rohana Mahbub (2012) asserts that the industry is prepared to embrace technologies in areas like prefabrication, assembly, and in the design, planning, and costing stages. However, this readiness is contingent on the capabilities of individual companies, influenced by their size, business type, and the support derived from government incentives and policies. While software use is widespread in design, scheduling, costing, and project management, actual on-site technology application remains limited. Musa et al. (2017) highlight modular construction as an innovative approach, particularly through the use of refurbished shipping containers. This method introduces a manufacturing stage and necessitates early coordination among contractors, manufacturers, and consultants. The case studies presented by Musa et al. (2017) showcase varying levels of industrialisation, from basic prefabrication to advanced robotic automation, emphasising the need for skilled workers even in automated environments.

The adoption of the "Design and Build" concept and Building Information Modelling (BIM), using software like Revit, also contributes to enhanced project outcomes. Aziz et al. (2019) suggest that a combinatorial concept for modular design has the potential to broaden opportunities for affordable housing by offering alternative design layouts that are cost-effective and time-saving. This approach could address the need for efficient and affordable housing solutions in Malaysia. Lee et al. (2021) explore the development of three-dimensional subsurface models using software like AutoCAD Civil 3D, identifying challenges in data collection due to the prevalence of data in hard copy or PDF format and the absence of a centralised soil investigation database system. This highlights the need for improved data management and standardisation to facilitate the adoption of geotechnical BIM in the Malaysian construction industry. Soto et al. (2021) discuss the emergence of virtual field experiences (VFEs) using software like Virtual Reality Geological Studio (VRGS) as a response to pandemic-related restrictions. VFEs provide an alternative to traditional field trips, allowing students to engage with geological studies remotely.

Table 2.4 presents a summary of key case studies that showcase the implementation of construction innovations in Malaysia. Each case study provides insights into the methods used and their practical applications during implementation.

Table 2.4: Case Studies of Construction Innovations in Malaysia.

Construction Innovation	Case Study	Details	Reference
Modular Prefabrication (Lightweight Steel)	Single-Storey Bungalow	The structure is prefabricated in a factory using hot-dip galvanised lightweight steel. 80% of the project timeline is completed in the factory. Adopted a 'Design and Build' concept, incorporating Design for Manufacturing and Assembly (DfMA) and Building Information Modelling (BIM) using Revit software. The manufacturing process employs robotic automation with Semi-Automated Mason (SAM) for welding. Utilises a 'Pick and Drop' concept for transportation to the site.	Musa et al. (2017)
Modular Prefabrication (Galvanised Steel)	Double-Storey Bungalow	Prefabricated in a factory using galvanised steel, with on-site work mainly focused on foundation construction. Shares the same project process as the single-story bungalow, with mechanisation and prefabrication techniques. Skilled machine operators and welders are required.	Musa et al. (2017)
Combinatorial Concept for Modular Design	Affordable Housing	Offers alternative design layouts that are cost-effective and timesaving compared to conventional systems.	Aziz et al. (2019)

Table 2.4 (Continued)

3D Subsurface Modelling (Geotechnical BIM)	Case Study 1: Petaling Jaya District, Selangor (Granitic Rock) Case Study 2: Kuala Selangor District, Selangor (Kenny Hill Formation)	Uses AutoCAD Civil 3D for modelling. Requires significant modelling and computational efforts due to complex tropical residual soil profiles. Different levels of detailing serve different engineering applications. Geotechnical BIM is "still a relatively new concept" in the Malaysian construction industry.	Lee et al. (2021)
Virtual Field Experiences (VFEs)	Kinta Valley Limestone (Virtual Reality Model)	Developed in response to pandemic-related restrictions. Uses software like Virtual Reality Geological Studio (VRGS). Allows students to learn at their own pace, display data at various scales, and view areas from multiple angles. Supports diverse data types from field, laboratory, or library.	Soto et al. (2021)

2.4 Drivers of Construction Innovation

Drivers of construction innovation are the key factors that encourage and support the adoption of new ideas, technologies, and practices within the industry. This section summarises the key drivers of construction innovation identified in past studies.

2.4.1 Organisational Culture and Leadership

2.4.1.1 Empowerment of innovation champions/leaders

The empowerment of innovation champions and leaders is a crucial driver of innovation in the construction industry. Champions, as noted by Blayse and Manley (2004), are essential for mobilising collective action around new ideas, possessing both technical competence and authority to overcome uncertainty and resistance. Tatum (1986, 1989) was one of the earliest researchers to identify specific roles, including executive champions who provide high-level sponsorship and resources for new ideas as essential to innovation. In addition, Bossink (2004) highlights that innovation leaders empower champions to develop ideas, stimulate collaboration, and implement innovative concepts. Gambatese and Hallowell (2011) also emphasise the importance of innovation champions in enabling successful innovation. It becomes clear that leadership plays a pivotal role, with committed leaders setting the agenda for industry-wide change (Kagioglou *et al.*, 2000; Oladapo, 2007). Overall, empowering champions through supportive leadership creates an ecosystem conducive to sustained innovation in the construction industry.

2.4.1.2 Training

Training emerges as a critical driver of innovation across multiple studies in the construction industry, with researchers emphasising its role in fostering technological adoption, skill development, and organisational adaptability. Ariono, Wasesa and Dhewanto (2022) highlight government-led training initiatives as pivotal for BIM innovation in Malaysia, where collaborations with institutions like MyBIM and software developers such as Autodesk provide structured programs to upskill industry professionals. Similarly, Bossink (2004) underscores training as essential for building technological capabilities and facilitating knowledge exchange within and between organisations, arguing that it directly enhances innovation by equipping employees with the skills to implement new processes. Chegu Badrinath, Chang and Hsieh (2016) further extend this focus to tertiary education, advocating for BIM training in academic curricula to bridge the gap between academia and industry, ensuring future professionals are equipped to drive innovation through advanced visualisation and communication tools. Furthermore, Eadie et al. (2013) identify a lack of expertise as a major barrier to BIM adoption, emphasising the need for targeted training to address skill gaps and accelerate industry-wide innovation. Likewise, Oladapo (2007) reinforces the importance of leadership training, noting that CEOs' computer literacy and perception of ICT benefits directly influence technology adoption in Nigeria's construction sector. Finally, Ozorhon, Oral and Demirkesen (2016) stress the role of training policies in activating innovation, particularly through human resources departments that enable personnel to adapt to evolving market demands. Collectively, these studies demonstrate that training, whether government-initiated, academically integrated, or organisationally driven, is indispensable for fostering innovation, addressing expertise gaps, and ensuring the construction industry remains competitive in an era of rapid technological change.

2.4.1.3 Integrated and informal R&D function

Integrated and informal R&D consistently emerges as a significant driver of innovation across various studies, particularly in industries like construction. Nam and Tatum (1992) emphasise that successful technology-push innovation relies on continuous, integrated, yet informal R&D efforts embedded within a firm's operations rather than being isolated activities. This approach encourages incremental improvements and fosters a culture of technological awareness at all organisational levels, enabling firms to proactively identify opportunities for innovation and shape client demands through advanced technologies. Similarly, Bossink (2004) highlights the importance of informal R&D functions within organisations, where managers monitor technological developments and market demands, share insights with colleagues, and decide on the adoption of new technologies or the development of new markets. He also underscores the coupling of R&D

officers with innovation projects to facilitate knowledge exchange and information sharing among stakeholders, including clients, architects, and contractors. Ariono, Wasesa and Dhewanto (2022) broaden this viewpoint by recognising integrated R&D as a crucial factor in the adoption of BIM in developing countries. They also advocate for additional research into performance-focused design and lean construction as a component of an innovation framework. Furthermore, Becerik-Gerber, Gerber and Ku (2011) stress the importance of integrating research with industry collaboration and multidisciplinary education to address complex challenges in the AEC sector. These studies collectively highlight that integrated R&D, whether formal or informal, enhances organisational responsiveness to technological advancements, facilitates collaboration across teams and projects, and drives sustained innovation by embedding research efforts into everyday operations.

2.4.1.4 Absorptive capacity

Absorptive capacity emerges as a pivotal driver of innovation across multiple studies, particularly in the context of BIM adoption and construction innovation. Ariono, Wasesa and Dhewanto (2022) explicitly identify absorptive capacity as one of the top drivers of BIM innovation in developing countries, emphasising its role in enabling firms to absorb and utilise external knowledge for technological adoption. Blayse and Manley (2004) further contextualise this by linking absorptive capacity to a firm’s technical competence and prior knowledge, arguing that organisations must possess a “critical mass” of skilled professionals to interpret and act on external research; it is a prerequisite for innovation. Gann (2001) also frames absorptive capacity as a function of ongoing technical capability and prior knowledge, underscoring its necessity for knowledge transfer and innovation. Eadie et al. (2013) further extend this perspective by highlighting absorptive capacity’s role in stakeholder collaboration during BIM implementation. They highlight that companies with greater absorptive capacity are more effectively equipped to capitalise on collaboration and overcome challenges like gaps in expertise, often alleviated through focused training. Collectively, these studies demonstrate that absorptive capacity is not merely a passive trait but an active enabler of innovation, requiring strategic investment in skills, knowledge, and organisational learning to foster technological adoption and competitiveness.

2.4.1.5 Corporate social responsibility

Corporate Social Responsibility (CSR) is increasingly recognised as a critical driver of innovation, fostering both environmental and organisational advancements. Ozorhon, Oral and Demirkesen (2016) highlight that CSR is crucial for boosting client satisfaction and enhancing corporate image, which in turn fosters innovation by building stakeholder trust and encouraging collaboration. Borger and Kruglianskas (2006), who establish a strong link between CSR strategies and improved environmental and innovative performance, emphasise that CSR initiatives can lead to project and company-level benefits. Similarly, Ozorhon and Oral (2017) reinforce the idea that CSR drives sustainability and innovation by aligning corporate practices with environmental goals, creating opportunities for green innovation. Supporting this perspective, studies like Green (2013) view CSR as a source of sustainability, which inherently promotes innovative practices aimed at reducing environmental impact. Collectively, these studies underscore that CSR not only serves as a platform for addressing societal and environmental concerns but also acts as a catalyst for innovation by driving sustainability-focused strategies, improving stakeholder engagement, and enhancing organisational competitiveness.

2.4.1.6 Leadership

Leadership emerges as a multifaceted driver of innovation in construction, particularly in driving technological adoption and fostering collaborative environments. Ariono, Wasesa and Dhewanto (2022) highlight innovation leaders as critical enablers of BIM adoption in developing countries, emphasising their role in formulating strategies, allocating resources, and overcoming institutional barriers. They position leaders alongside training and client demand-pull as key factors within the process category, which is the second-highest driver of BIM innovation. For instance, government agencies in Malaysia, such as the Construction Industry Development Council (CIDB), act as innovation leaders by initiating policies, training programs, and collaborations to advance BIM adoption. Ozorhon, Oral and Demirkesen (2016) further reinforce leadership's centrality, defining it as a main enabler of innovation that shapes the "project spirit" by fostering team cohesion and directing attention toward innovation. They note that project managers, as leaders, motivate teams, resolve conflicts, and integrate efforts across stakeholders, as seen in case studies where leadership enabled the adoption of modern methods of construction (MMCs) and lean practices. Building on foundational work by previous researchers, the authors underscore that leaders with technical expertise and authority are essential to navigate uncertainties and drive technology-push innovation, aligning client demands with organisational capabilities. Collectively, these studies demonstrate that leadership is not merely a top-down directive but a dynamic force that integrates strategic vision, collaboration, and adaptability to drive innovation in construction.

2.4.2 Collaboration and Coordination

2.4.2.1 Coordination of participating groups

Coordination between participating groups emerges as a multifaceted driver of innovation across construction and related industries, fostering collaboration, knowledge integration, and efficient problem-solving. Ariono, Wasesa and Dhewanto (2022) emphasise that coordination enhances sustainability and efficiency through tools like Revit and Navisworks, which streamline clash detection and multidisciplinary design processes. Likewise, Becerik-Gerber, Gerber and Ku (2011) highlight the role of academic-industry partnerships in fostering collaboration skills, advocating for BIM integration in curricula to prepare graduates for teamwork-driven innovation. Similarly, Bossink (2004) and Tatum (1989) underscore coordination as a foundational driver, ensuring alignment between client demands and project execution. Gambatese and Hallowell (2011) link coordination to management practices, such as formal innovation meetings and open communication, which institutionalise collaborative experimentation. Building on this, Huggins and Thompson (2017) emphasise the importance of relational governance, where strategic alliances and formal partnerships replace informal networks, enabling systematic knowledge exchange and fostering innovation. Hunt and Gonzalez

(2018) further note that diverse professional networks and strong contractor-consultant relationships at the project level enhance inter-organisational learning and idea diffusion. Complementing this perspective, Oladapo (2007) ties coordination to ICT adoption, arguing that digital tools improve communication and decision-making across teams, transforming traditional workflows. Similarly, Ozorhon and Oral (2017) highlight early contractor involvement as critical for fostering cooperative environments where coordinated input from stakeholders leads to value-adding solutions. Collectively, these studies demonstrate that coordination, whether through technical tools, educational reforms, strategic partnerships, or management practices, is essential for reducing inefficiencies, fostering creativity, and sustaining innovation in project-based industries like construction.

2.4.2.2 Creation of knowledge networks

The establishment of knowledge networks is broadly acknowledged as a key factor in promoting innovation in various sectors, especially in construction and manufacturing sector. Ariono, Wasesa and Dhewanto (2022) identify knowledge exchange as a key driver of BIM innovation in developing countries, emphasising the importance of facilitating information sharing among stakeholders to enhance collaboration and innovation outcomes. Similarly, Becerik-Gerber, Gerber and Ku (2011) highlight the need to break down silos in AEC education and integrate disciplines to mirror industry practices, fostering knowledge flow and enabling innovation through collaboration. Blayse and Manley (2004) emphasise the role of "innovation brokers," such as universities and research bodies, in orchestrating cooperation and disseminating knowledge. They also advocate for the incorporation of project experiences into ongoing business activities to safeguard tacit knowledge, which is crucial for sustained innovation. Likewise, Bossink (2004) categorises knowledge exchange as one of the four main drivers of innovation, highlighting the creation and stabilisation of knowledge networks involving universities, research institutes, and businesses. He underscores government-led initiatives, such as sustainable construction knowledge centres, as effective mechanisms for promoting innovation through knowledge sharing. Oladapo (2007) , on the other hand, connects ICT adoption to knowledge transfer, noting that digital tools facilitate communication between project teams and enable the development of new knowledge for innovation. Wang, Lin and Li (2019) who discuss regional innovation systems also emphasise the importance of linking knowledge bases with enterprises and research institutions to drive localised innovation. Finally, Wei and Lam (2014) stress the significance of knowledge management in improving capabilities through learning from past projects and interactions with participants. Collectively, these studies demonstrate that knowledge networks, whether facilitated by ICT tools, institutional collaboration, or government initiatives, are essential for fostering innovation by enabling efficient knowledge flow, integration of diverse expertise, and continuous learning across projects and organisations.

2.4.2.3 Strategic alliances

Strategic alliances are essential for innovation in the fragmented construction industry. Ariono, Wasesa and Dhewanto (2022) identify strategic alliances and long-term relationships as drivers of BIM innovation in developing countries. Kagioglou et al. (2000) also emphasise the importance of integrating processes and teams through strategic alliances involving contractors, clients, and IT specialists to address inefficiencies and foster innovation, supported by government-stimulated research programs. Similarly, Kangari and Miyatake (1997) highlight that strategic alliances contribute to innovative construction technology development in their research while citing the collaboration between Shimizu Corporation and Mitsubishi Heavy Industries in Japan. Furthermore, Bossink (2004) notes alliances as a means to leverage capabilities and share financial risks, particularly in sustainable construction. In addition, Miozzo and Dewick (2002) emphasise alliances and links to external knowledge sources for developing operational capabilities, exemplified by the Nordic Construction Company's partnerships. These studies collectively show that strategic alliances drive innovation by enabling knowledge sharing, risk mitigation, and the integration of diverse expertise.

2.4.2.4 Programs promoting collaboration

Programs promoting collaboration are recognised as key drivers of innovation, particularly in BIM adoption and construction. Ariono, Wasesa and Dhewanto

(2022) identify such programs as critical for BIM innovation in Nigeria, emphasising their role in fostering knowledge sharing and skill development. Similarly, Bossink (2004) highlights collaborative arrangements between architects, contractors, and researchers as essential for translating scientific insights into practical applications. Government-led initiatives, such as programs stimulating cooperation between small firms and contractors, enable organisations to share expertise and build sustainable competencies. These programs bridge gaps between academia and industry, ensuring that knowledge exchange is institutionalised and innovation is sustained. By fostering cross-disciplinary collaboration and institutional support, such initiatives address fragmentation in industries like construction, ultimately driving technological adoption and long-term innovation.

2.4.3 Market and Client Pressures

2.4.3.1 Market pull/client requirements

Market pull and client requirements are pivotal drivers of innovation in construction, with clients exerting significant influence through their demands for higher standards, adaptability, and technological adoption. Ariono, Wasesa and Dhewanto (2022) highlight client demand as a key driver of BIM innovation in developing countries like China and Croatia, where client expectations create environments conducive to technological adoption. Similarly, Blayse and Manley (2004) emphasise that experienced and demanding clients stimulate innovation by pushing for improved lifecycle performance, flexibility, and quality. However, Bossink (2004) notes that while market pressure often drives innovation, traditional client preferences in regions like the Netherlands can hinder sustainable advancements. Building on this perspective, Nam and Tatum (1992) and Meng and Brown (2018) reinforce the dominance of market-pull forces, with client needs and competition driving project-based innovations. Eadie et al. (2013) and Van Nguyen (2023) further underscore the role of client requirements, particularly in sustainable construction, where government clients often lead BIM adoption and project performance improvements. Additionally, Ozorhon, Oral and Demirkesen (2016) and Owolabi et al. (2019) stress that clients pressure contractors to adopt innovative processes, fostering strategies to address unpredictability and meet evolving expectations. Collectively, these studies demonstrate that client demands and market dynamics are central to driving innovation, necessitating alignment between industry strategies and stakeholder needs to sustain competitiveness.

2.4.3.2 Competition level

Increased competition is a critical driver of innovation in the construction industry, as firms seek to enhance efficiency, quality, and competitiveness through technological adoption and process improvements. Gambatese and Hallowell (2011) emphasise that innovation is motivated by competition, with cost savings, improved quality, and productivity gains directly contributing to competitive advantage. Similarly, Ozorhon, Oral and Demirkesen (2016) highlight that innovation is essential for firms to compete effectively in a globalised market, driven by the need to improve performance amid rising competition. Tatum (1989) further notes that successful project innovations create long-term competitive advantages by shaping business strategies. Expanding this perspective, Jensen (2017) illustrates how staged competitions in industries like automotive provide platforms for innovation diffusion, though this concept is less explored in construction. Likewise, Ratana Singaram et al. (2023) argue that technologies like BIM and IoT enhance competitiveness by improving project outcomes and enabling sustainable practices, while Ozorhon and Oral (2017) stress that technological advancements (e.g., communication tools, new materials) help firms devise innovative solutions to stay competitive. Collectively, these studies underscore that competition pressures firms to innovate, adopt modern technologies, and align strategies with market demands to maintain or gain a competitive edge.

2.4.3.3 Design trends

Design trends are widely recognised as a significant driver of innovation in the construction industry, particularly due to increasing client demands for complex and technologically advanced designs. Ozorhon, Oral and Demirkesen (2016) emphasise that design plays a crucial role in innovation by integrating technical capabilities with market demands and opportunities. They note that clients often expect designers to utilise integrated technologies and create innovative designs that push the boundaries of construction technology. Similarly, Owolabi et al. (2019) rank design trends among the top three drivers of innovation, highlighting how innovative design trends stimulate advancements in construction processes and technologies. Ozorhon and Oral (2017) further identify collaborative design and construction arrangements, including partnerships and supply chain management, as essential factors for achieving excellence and fostering innovation in the construction industry. Together, these studies demonstrate that design trends not only respond to client expectations but also drive the development of new capabilities, technologies, and collaborative practices that enhance competitiveness and innovation within the industry.

2.4.3.4 Project complexity

Project complexity is a significant driver of innovation in the construction industry, as it necessitates advanced solutions to meet challenging demands. Nam and Tatum (1992) highlight that technological advancements often precede problems, with innovations arising from increasing the magnitude of known technologies or integrating existing ones. They argue that complex configurations, such as advanced structural designs, push construction firms to innovate by leveraging informal R&D and long-term strategies. This challenges the traditional belief that the "problem is mother to construction innovation". This perspective aligns with Ozorhon and Oral (2017), who identify project complexity as a primary driver, noting that bespoke designs and unpredictable challenges compel firms to innovate at the project level to meet unique requirements. Together, these studies demonstrate that project complexity driven by technological advancements and client demands acts as a catalyst for innovation, requiring firms to adopt new technologies and strategies to address unique challenges effectively.

2.4.4 Technology and Innovation Process

2.4.4.1 Technology push

Technology push is a significant driver of innovation in the construction industry, where advancements in tools, materials, and processes often precede or complement market demand. Becerik-Gerber, Gerber and Ku (2011) highlight how emerging technologies like BIM, sustainability tools, and virtual learning applications drive adoption and integration into industry practices, particularly in education and project management. Meng and Brown (2018) frame this as part of a dual dynamic, where technology-push interact with market forces like competition and client needs to shape innovation. Nam and Tatum (1992) emphasise that technology push can even precede demand-pull forces, creating opportunities for innovation before market needs fully materialize. Likewise, Owolabi et al. (2019) reinforce this by identifying ICT development as a major driver of innovation in Nigeria, while Ozorhon, Oral and Demirkesen (2016) note that ICT and new materials not only solve problems but also foster collaboration and skill development among employees. Collectively, these studies demonstrate that technology push fuels innovation by introducing transformative solutions, enhancing adaptability, and creating environments where firms and workers are motivated to refine and implement advancements.

2.4.4.2 Integrated design-build

The integration of design and build activities is a critical driver of innovation in the construction industry, particularly for medium to large firms. Bossink (2004) highlights that early collaboration between architects, clients, and contractors fosters interdisciplinary problem-solving, enabling the implementation of innovative concepts like ecological water management systems. Building on this, Meng and Brown (2018) note that this integration is especially effective for larger firms, which leverage design-build partnerships to overcome traditional silos between design and construction phases. Similarly, Ozorhon and Oral (2017) reinforce this, emphasising that integrated teams, early contractor involvement, and cooperative project cultures encourage experimentation and value-adding solutions. Early contractor participation enhances design-stage contributions and creates environments where stakeholders collaborate to address challenges proactively. Collectively, these studies demonstrate that integrating design and build processes not only improves communication and efficiency but also cultivates a culture of innovation, enabling firms to adopt novel technologies and sustainable practices while aligning client demands with constructability.

2.4.4.3 Technology capability

Technological capability is a pivotal driver of innovation in the construction industry, enabling organisations to experiment with and implement advanced methods and tools. Bossink (2004) defines it as technical factors that facilitate innovative products and processes, operating at industry-wide, organisational, and interorganisational levels through mechanisms like technology programs, pilot project financing, and technology fusion. Similarly, Nam and Tatum (1992) challenge the notion that innovation is solely demand-driven in their study, arguing instead that technological advancements can proactively shape owner demands and problem-solving approaches. Their emphasis on continuous R&D and strategic leadership underscores how firms can leverage technological capability to gain competitive advantages and identify new opportunities for project innovation. Together, these studies highlight that technological capability not only supports innovation but actively drives it, fostering a culture of experimentation and competitiveness in the sector.

2.4.4.4 Technology fusion

The literature highlights technology fusion as an important driver of innovation in the construction industry, emphasising its role in combining different technologies to create innovative solutions. Bossink (2004) identifies technology fusion as a key component of technological capability, which enables organisations to develop innovative products and processes. By merging diverse technological approaches, firms can experiment with and implement innovative practices, enhancing their ability to adapt to complex challenges and improve project outcomes. Similarly, Nam and Tatum (1992) suggest that combining technologies could naturally arise from a proactive strategy. Together, these studies underscore that technology fusion is a critical enabler of innovation, fostering collaboration, experimentation, and the development of advanced solutions across the construction sector.

2.4.5 Financial, Regulatory, and Sustainability Support

2.4.5.1 Innovation stimulating regulations

Regulations, particularly performance-based standards, are widely recognised as drivers of innovation in the construction industry. Ariono, Wasesa and

Dhewanto (2022) highlight government-led initiatives in Malaysia and China, where regulations and collaborations with research centres spurred BIM adoption to enhance project performance and sustainability. Similarly, Blayse and Manley (2004) highlight that performance-based regulations, which focus on outcomes rather than rigid methods, promote innovation by allowing flexibility for organisations to develop novel solutions. However, their effectiveness depends on the technical knowledge of regulators, as poorly designed regulations can hinder innovation by reinforcing existing practices. Building on this perspective, Bossink (2004) supports this view by noting that prescriptive regulations often stifle creativity, while performance-based approaches stimulate innovation by pushing organisations toward specific goals, such as sustainability. For example, the Dutch government used environmental and building acts to enforce high standards, driving innovation to meet these requirements. Ozorhon, Oral and Demirkesen (2016) emphasise that performance standards exert pressure on construction companies to innovate, fostering advancements in technology and practices. Tatum (1989) adds that collaboration with regulatory agencies is essential for securing approval for innovative methods and resolving potential issues. Collectively, these studies demonstrate that well-designed performance-based regulations can drive innovation by balancing flexibility with accountability, provided regulators possess the necessary expertise and industry collaboration is fostered.

2.4.5.2 Project performance improvement

Enhancing project performance improvement is a major motivating factor for innovation in construction, particularly in the adoption of technologies like BIM. Ariono, Wasesa and Dhewanto (2022) identify increased performance and productivity as primary motivators for BIM innovation in developing countries, where efficiency and client satisfaction are prioritised. Likewise, Eadie et al. (2013) emphasise that BIM implementation enhances project performance across all stages, with the expectation and realization of improved outcomes acting as strong incentives for adoption. Similarly, Ozorhon, Oral and Demirkesen (2016) and Ozorhon and Oral (2017) further highlight that construction firms view innovation as a means to improve project success in terms of time, cost, quality, and client satisfaction, positioning performance improvement as a central driver of innovation. Van Nguyen (2023) reinforces this by noting that improving project performance is critical for sustainable construction practices, including modular methods. Collectively, these studies underscore that the pursuit of better project outcomes, such as efficiency gains, cost reductions, and quality improvements, drives technological and process innovations, with BIM serving as a pivotal tool for optimising collaboration and execution.

2.4.5.3 Environment and sustainability

Environmental and sustainability concerns are key drivers of innovation in the construction industry, pushing firms to adopt greener practices and advanced technologies. Ariono, Wasesa and Dhewanto (2022) highlight that sustainability pressures in developing countries have spurred innovations like green building standards and smart city initiatives, where BIM enhances material maintenance and IoT/Big Data integration. Similarly, Meng and Brown (2018) reinforce this, identifying sustainability as a primary driver of innovation, with sustainable practices becoming a central agenda. Likewise, Ozorhon, Oral and Demirkesen (2016) emphasise that environmental pressures, such as climate change, compel the industry to reduce ecological impacts, fostering innovations in sustainable equipment, techniques, and products. Building on this perspective, Ozorhon and Oral (2017) further underscore environmental sustainability as a core motivator for construction innovation. Together, these studies demonstrate that sustainability not only drives green technologies but also reshapes processes, materials, and project designs, positioning it as a critical force in modernising the industry.

2.4.5.4 Subsidies

Government subsidies are recognised as a key driver of innovation in the construction industry, offering financial incentives that reduce risks and encourage technological advancements. Bossink (2004) highlights how subsidies for sustainable applications and materials are integrated into project requirements, with authorities informing clients and architects to promote their adoption. Building on this, Gong and Wang (2022) emphasise that subsidies complement firms' R&D investments, fostering innovation by signalling credibility to private investors and mitigating financial barriers. Similarly, Ozorhon and Oral (2017) note that industry-wide schemes, such as research grants and government programs, reward innovators while reducing perceived risks, creating an environment conducive to experimentation and progress. However, Wang, Lin and Li (2019) caution that subsidies are most impactful in early industrial stages but risk diminishing returns if overused. Collectively, these studies demonstrate that subsidies are critical for stimulating innovation, particularly in sustainable practices and R&D, though their effectiveness hinges on strategic implementation to avoid inefficiencies and ensure long-term growth.

2.5 Summary of Drivers of Innovations

Tables 2.5 and 2.6 below provide a summary of the drivers that contribute to innovation, as identified in the literature review.

Note to Table 2.5

Authors: [A] is Akintoye, Goulding and Zawdie (2012), [B] is Ariono, Wasesa and Dhewanto (2022), [C] is Becerik-Gerber, Gerber and Ku (2011), [D] is Blayse and Manley (2004), [E] is Bossink (2004), [F] is Eadie et al. (2013), [G] is Gambatese and Hallowell (2011), [H] is Gong and Wang (2021), [I] is Huggins and Thompson (2016), [J] is Hunt and Gonzalez (2018), [K] is Jensen (2017), [L] is Kagioglou et al. (2000), [M] is Kangari and Miyatake (1997), [N] is Meng and Brown (2018), [O] is Miozzo and Dewick (2002), [P] is Nam and Tatum (1992), [Q] is Oladapo (2007), [R] is Owolabi et al. (2019), [S] is Ozorhon and Oral (2017), [T] is Ozorhon, Oral and Demirkesen (2016), [U] is Ratana Singaram et al. (2023), [V] is Tatum (1986), [W] is Tatum (1989), [X] is Van Nguyen (2023), [Y] is Wang, Lin and Li (2019), [Z] is Wei and Lam (2014), and [AA] is Yadav, Prabhu and Chandy (2007).

Table 2.5: Literature Map for Drivers.

Ref	Drivers	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
	Organisational Culture & Leadership																											
1	Empowerment of innovation champions/ leaders				✓	✓		✓					✓					✓			✓		✓	✓				
2	Training		✓			✓	✓											✓			✓							
3	Integrated and informal R&D function		✓	✓		✓											✓											
4	Absorptive capacity		✓		✓		✓																					
5	Corporate responsibility																			✓	✓							
6	Leadership		✓																		✓							

Table 2.5 (Continued)

Ref	Drivers	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
	Collaboration & Coordination																											
7	Coordination of participating groups	✓	✓	✓		✓		✓		✓	✓							✓		✓								
8	Creation of knowledge networks	✓	✓		✓	✓												✓								✓	✓	
9	Strategic alliances		✓			✓							✓	✓		✓												
10	Programs promoting collaboration		✓			✓																						

Table 2.5 (Continued)

Ref	Drivers	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
	Market & Client Pressures																											
11	Market pull/client requirement	✓	✓		✓	✓	✓								✓	✓	✓		✓	✓	✓		✓		✓			✓
12	Competition level		✓				✓	✓				✓								✓	✓	✓		✓				
13	Design trends																		✓	✓	✓							
14	Project complexity																✓		✓	✓								

Table 2.5 (Continued)

Ref	Drivers	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
	Technology & Innovation Process																											
15	Technology push			✓											✓		✓		✓		✓							
16	Integrated design-build					✓									✓					✓								
17	Technology capability					✓											✓											
18	Technology fusion					✓								✓														

Table 2.5 (Continued)

Ref	Drivers	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
	Financial, Regulatory, & Sustainability Support																											
19	Innovation stimulating regulations				✓	✓														✓	✓			✓				
20	Project performance improvement		✓				✓													✓	✓				✓			
21	Environment and sustainability		✓												✓					✓	✓							
22	Subsidies					✓			✓											✓						✓		

Table 2.6: Final Summary of Drivers of Innovations.

Theme	Drivers	Total Frequency
Organisational Culture & Leadership	Empowerment of innovation champions/ leaders	8
	Training	5
	Integrated and informal R&D function	4
	Absorptive capacity	3
	Corporate responsibility	2
	Leadership	2
Collaboration and Coordination	Coordination of participating groups	9
	Creation of knowledge networks	7
	Strategic alliances	5
	Programs promoting collaboration	2
Market and Client Pressures	Market pull/client requirement	14
	Competition level	8
	Design trends	3
	Project complexity	3
Technology and Innovation Process	Technology push	5
	Integrated design-build	3
	Technology capability	2
	Technology fusion	2
Financial, Regulatory, & Sustainability Support	Innovation stimulating regulations	5
	Project performance improvement	5
	Environment and sustainability	4
	Subsidies	4

2.6 Barriers of Construction Innovation

Barriers to construction innovation refer to the factors that hinder or restrict the adoption and implementation of innovative ideas, technologies, and practices within the industry. This section summarises the key barriers to construction innovation identified in past studies.

2.6.1 Organisational Challenges

2.6.1.1 Unsupportive organisational culture

A lack of support within an organisational culture is commonly acknowledged as a major obstacle to innovation in various industries, especially in the construction industry. Arayici, Khosrowshahi, Farzad Ponting and Mihindu (2009) identify reluctance to adopt new workflows or train staff as a primary reason for the slow implementation of BIM in UK construction companies, reflecting resistance to change within organisations. Similarly, Ariono, Wasesa and Dhewanto (2022) identify inappropriate culture and context as the most prevailing barrier to BIM innovation in developing countries like Iran. They argue that fostering a BIM-oriented culture through stakeholder involvement and digital transformation processes can address these challenges. In addition, Ozorhon, Oral and Demirkesen (2016) highlight the construction industry's resistance to adopting new practices and technologies, emphasising that unsupportive organisational cultures discourage risk-taking, trust, and experimentation, which are the key elements for innovation. Likewise, Tatum (1986) points out that rigid institutional frameworks and risk-averse attitudes within organisations stifle creativity and long-term investments, suggesting that innovation-friendly climates are essential for progress. Furthermore, Wei and Lam (2014) rank organisational culture as the third most significant barrier to innovation at the project level, citing issues such as poor motivational structures, lack of managerial support, and a "business-as-usual" mindset that suppresses enthusiasm for change as major reasons for remaining unchanged. Collectively, these studies underscore the importance of cultivating proactive, collaborative, and forward-thinking organisational cultures to overcome barriers and drive innovation effectively.

2.6.1.2 Lack of incentives

The lack of incentives is consistently identified as a significant barrier to innovation in the construction industry across multiple studies. Tatum (1986) points out that construction firms are reluctant to put money into new technologies due to insufficient financial incentives and the perceived risks of R&D, which are further exacerbated by industry fragmentation. A more recent study by Ariono, Wasesa and Dhewanto (2022) also highlight inadequate policy-driven incentives as a major obstacle to BIM adoption in Iran, compounded by high costs and the dominance of traditional methods. Similarly, Rose, Manley and Widen (2019) emphasise that incentives in road construction often favour cost-saving innovations over those offering broader benefits, limiting consultants' ability to champion complex design innovations. Collectively, these studies underline that addressing incentive structures, whether through policy reform, balanced project priorities, or financial motivations, is crucial for fostering innovation in construction.

2.6.1.3 Organisational rigidity

Organisational rigidity is consistently identified as a significant barrier to innovation across various studies, particularly in the construction industry. Gambatese and Hallowell (2011) argue that closed, conservative, and highly standardised organisational cultures stifle innovation by restricting the development and implementation of new ideas. They emphasise that overly restrictive, complicated, or multi-layered organisational structures hinder creativity and suggest fostering open cultures with innovation champions, knowledge management systems, and upper management support to encourage innovation. Expanding on this, Shabanesfahani (2012) highlights rigid boundary strength between firms in networks as a major obstacle to systemic innovation diffusion, noting that flexible boundaries enable faster adoption of innovations. The traditional organisation of construction processes perpetuates outdated practices and inhibits investment in innovation. Likewise, Tatum (1989) identifies bureaucratic rigidity in larger firms as a barrier to innovation, emphasising that structural barriers, both vertical and horizontal, prevent collaboration across departments and stifle team spirit. He recommends keeping flexibility in the size and arrangement of units while creating specific connections for both internal and external coordination to foster innovation. Collectively, these studies underline the need for adaptable organisational structures and cultures that prioritise collaboration, flexibility, and proactive leadership to overcome rigidity and foster innovation in the construction sector.

2.6.1.4 Fear of change

Fear of change is a widely acknowledged barrier to innovation in the construction industry, as it creates resistance to adopting new technologies and practices. Arayici, Khosrowshahi, Farzad Ponting and Mihindu (2009) highlight that multi-disciplinary teams often clash with traditional methodologies due to knowledge-sharing impediments, and there is reluctance to initiate new workflows or train staff, reflecting resistance to adopting innovative approaches like BIM. Gambatese and Hallowell (2011) further identify clients' fear of change as a significant obstacle, particularly in intergovernmental organisations (IGOs), where it hinders transformative improvements. Similarly, Owolabi et al. (2019) rank cultural aversion to change as the sixth most significant barrier to innovation in Nigeria, emphasising that innovation inherently brings change, which resistant cultures fail to support. In summary, fear of change, whether stemming from clients, employees, or organisational cultures, significantly hampers innovation by creating resistance to new ideas and practices.

2.6.1.5 Lack of recognition from clients

The lack of recognition from clients is a significant barrier to innovation in the construction industry, as highlighted by multiple studies. Gambatese and Hallowell (2011) identify that clients often fail to recognise innovation, particularly in intergovernmental organisations (IGOs), which obstructs its implementation. Building on this. Wei and Lam (2014) highlight the essential importance of relationships between clients and industries, identifying them as the primary obstacle to innovation. They observe that clients who are both experienced and cooperative tend to be more supportive of adopting innovation, though such clients are uncommon. Most clients exhibit conservative attitudes, preferring well-proven solutions over innovative designs, which weakens the "demand-pull" for innovation. These findings align with Blayse and Manley (2004) who highlight that clients play a fundamental role in shaping innovation outcomes but often lack the knowledge or willingness to demand innovative solutions. This conservatism limits opportunities for progress and discourages stakeholders from investing in innovative solutions.

2.6.2 Financial and Resources Limitations

2.6.2.1 Lack of financial resources

Lack of financial resources is a widely recognised barrier to innovation in the construction industry. Ariono, Wasesa and Dhewanto (2022) highlight that financial resistance and the high costs associated with software acquisition and implementation pose major challenges to BIM adoption, particularly in developing countries like Iran and Nigeria. This issue is compounded by the dominance of traditional methods, which further discourages investment in innovative solutions. Similarly, Gong and Wang (2022) emphasise that technological innovation requires substantial capital investment, noting that firms with high debt ratios or low operational efficiency face constraints in allocating funds for R&D. Ozorhon, Oral and Demirkesen (2016) reinforce this perspective by highlighting the critical role of financial resources in innovation development, observing that insufficient funding often prevents contractors from adopting new technologies while they remain under pressure to deliver projects within tight budgets. This issue is especially pronounced for small and medium-sized enterprises (SMEs), as highlighted by Ratana Singaram et al. (2023), who note that such firms often lack the financial capacity to purchase expensive software or machinery essential for innovation. Blayse and Manley (2004) similarly argue that the construction industry's dominance by small participants with constrained resources limits their ability to undertake innovative efforts. Wei and Lam (2014) further rank insufficient budgets as the most significant resource-related barrier, explaining that financial constraints compel contractors to rely on traditional solutions rather than explore costly radical innovations. Collectively, these studies underline how inadequate financial resources hinder innovation by restricting investments in R&D, advanced technologies, and transformative practices.

2.6.2.2 Preference for quick pay-off opportunities

The preference for quick-payoff opportunities is a significant barrier to innovation in the construction industry, as highlighted by Akintoye, Goulding and Zawdie (2012). They argue that the industry's short-term orientation limits engagement in innovation activities, as firms prioritise immediate returns over long-term investments (Akintoye, Goulding and Zawdie, 2012, p. 57). Their findings align with Tatum (1989) who highlights that intense competition and owners' demands for cost-effective solutions drive contractors to focus on inexpensive and quick solutions rather than riskier, transformative innovations. He also highlights the significance of creating organisational structures that promote a long-term outlook and the patience to wait for substantial returns. This short-term focus perpetuates reliance on traditional methods and discourages experimentation, ultimately hindering progress.

2.6.2.3 Operational resources gap

Operational resource gaps, including financial constraints, are significant barriers to innovation in the construction industry. Meng and Brown (2018) highlight that larger firms, with greater financial resources, are better equipped to invest in research and development (R&D) and tolerate the risks associated with adopting new technologies, while smaller firms face limitations in resources and capabilities that hinder their ability to innovate effectively. Gong and Wang (2022) reinforce this point by emphasising the importance of innovation inputs such as capital and R&D investments, noting that state-owned firms often have more sufficient funds compared to private firms. Additionally, Ozorhon, Oral and Demirkesen (2016) identify material shortages as a critical operational barrier, with the unavailability of advanced materials negatively impacting construction processes and slowing innovation adoption. These findings collectively underline how financial limitations and resource disparities restrict innovation by reducing access to necessary tools and limiting experimentation.

2.6.3 Technical and Knowledge Gaps

2.6.3.1 Limited innovation knowledge

Limited knowledge of innovation is a significant barrier to the adoption of Building Information Modeling (BIM) and other innovative practices in the construction industry, particularly in developing countries. Ariono, Wasesa and Dhewanto (2022) highlight that a lack of research and understanding about BIM hinders its implementation in countries like Nigeria, where stakeholders struggle with unclear benefits and standardised procedures. Similarly, Gambatese and Hallowell (2011) identify limited knowledge as a major factor inhibiting the diffusion of technical innovations, emphasising the need for research to identify high-potential innovations for the industry. The issue extends beyond individual stakeholders to public clients, as Lenderink et al. (2020) note that many lack the knowledge and experience needed to stimulate or assess innovation effectively in construction projects. This gap limits opportunities for transformative solutions, as clients often fail to recognise the potential benefits of advanced practices like BIM. Tan et al. (2019) further highlight "misunderstanding of BIM" as a critical barrier, where stakeholders fail to grasp its concepts and processes, creating risks during implementation. Shabanesfahani (2012) also points out that poor knowledge transfer mechanisms hinder firms' ability to absorb and integrate new technologies into organisational practices. These studies align with Webb (1981) who connects this lack of knowledge to outdated practices and restrictive regulations, arguing that these barriers often stem from limited awareness or understanding of innovations. This perpetuates reliance on traditional methods and slows progress toward modernisation. Collectively, these studies underline how limited knowledge, whether due to insufficient research, misunderstanding, or poor knowledge transfer, restricts innovation by preventing stakeholders from leveraging advanced technologies effectively.

2.6.3.2 Lack of technical capabilities

The absence of technical capability is a significant obstacle to innovation in the construction sector, especially regarding the implementation of Building Information Modeling (BIM) and other advanced technologies. Arayici, Khosrowshahi, Farzad Ponting and Mihindu (2009) highlight that transitioning to BIM requires skilled personnel to manage training, resources, content creation, team collaboration, and new workflows, emphasising the rising skills gap as a major challenge. Shabanesfahani (2012) expands on this by identifying deficits in technical capabilities such as inadequate knowledge of building systems and green construction, poor understanding of knowledge transfer mechanisms, and insufficient skills for adapting innovative products to existing systems. These deficiencies hinder firms' ability to adopt sustainable practices and integrate new technologies effectively. The issue is further compounded by regional and sector-specific challenges. Tan et al. (2019) note that the absence of domestic-oriented BIM tools and standards in China limits the practical application of BIM in prefabricated construction projects. Similarly, Wang, Adetola and Abdul-Rahman (2015) emphasise that the lack of technical expertise in utilising BIM tools is the most significant challenge for Mechanical, Electrical, and Plumbing (MEP) firms in Nigeria. Collectively, these studies demonstrate how insufficient technical skills, inadequate knowledge transfer mechanisms, and the absence of tailored tools or standards restrict innovation by preventing stakeholders from leveraging advanced technologies effectively.

2.6.3.3 Lack of experienced and qualified staff

The literature highlights that insufficient experienced and skilled personnel is a major obstacle to innovation, especially within the construction sector and the implementation of Building Information Modeling (BIM). Ariono, Wasesa and Dhewanto (2022) highlight that a lack of expertise is a major challenge to BIM innovation in countries like Malaysia, Saudi Arabia, and Nigeria, where technical skills are insufficient to meet the demands of advanced technologies. Similarly, Ozorhon, Oral and Demirkesen (2016) stress that innovation requires qualified staff at all levels, especially key individuals such as innovation directors and technology managers who drive technological advancements. The impact of this skills shortage extends to specific sectors within the industry. Rose, Manley and Widen (2019) how a lack of expertise in the Australian road construction industry restricts the ability to assess and adopt new products, further stalling progress. Wang, Adetola and Abdul-Rahman (2015) reinforce this by identifying the lack of technical expertise in using BIM tools as a major challenge for MEP firms in Nigeria. Collectively, these studies show that insufficient technical expertise across various roles hinders innovation by limiting organisations' ability to adopt and implement advanced technologies effectively.

2.6.4 Project-Specific and Structural Constraints

2.6.4.1 Temporary nature of projects

The temporary nature of construction projects is a significant barrier to innovation, as highlighted in various studies. Akintoye, Goulding and Zawdie (2012) note that the transient nature of project alliances, involving numerous parties with limited communication, restricts the application of innovative solutions across projects. Projects are temporary coalitions that disband upon completion, posing challenges for long-term knowledge management practices. Similarly, Blayse and Manley (2004) emphasise that the one-off nature of construction projects leads to discontinuities in knowledge development and transfer, hindering organisational memory and reducing incentives to innovate. Davidson (2013) further highlights the industry's fragmentation and lack of continuity, which inhibit systemic innovation. Maghsoudi, Duffield and Wilson (2016) reinforce these points by noting that the "one-of-a-kind" nature of projects and temporary collaboration among multiple participants complicate innovation efforts. Wei and Lam (2014) also emphasise that temporary project structures break the "knowledge loop," hampering knowledge diffusion and organisational memory. Likewise, Hardie (2010) underscores the challenges posed by temporary linkages between companies and short-lived project teams, which inhibit coordination and knowledge sharing. Collectively, these studies show how the transient characteristics of construction projects limit knowledge retention, hinder organisational learning, and reduce the scalability of innovations.

2.6.4.2 Project-based production

The project-oriented production approach in the construction industry poses a considerable obstacle to innovation because of its fundamental traits of fragmentation, temporality, and discontinuity. Akintoye, Goulding and Zawdie (2012) highlight that the temporary nature of construction projects and their fragmented alliances limit the ability to capture and diffuse innovation within and across projects. This aligns with Blayse and Manley (2004), who emphasise that the one-off nature of most building projects leads to discontinuities in knowledge development and transfer, reducing organisational learning and incentives to innovate. Davidson (2013) expands on this by noting that the fragmented project-by-project modus operandi creates organisational problems that hinder systemic innovation, necessitating a systems approach to overcome these challenges. Lenderink et al. (2020) further point out that the limited production volume in project-based models makes it difficult for firms to recover investments in innovation, favouring incremental over radical innovations. In addition, Wei and Lam (2014) explain that short-term budgets and planning horizons strain investment in innovation, dividing efforts into separate segments and suppressing long-term success. The multi-firm collaboration model also exacerbates these challenges. Rose, Manley and Widen (2019) describe how the complex multi-firm production model results in disjointed relationships across project networks, impeding knowledge-sharing and collaboration. Hardie (2010) reinforces this by highlighting how the strong focus on individual project outcomes makes coordination with external stakeholders difficult and often deprioritised. Collectively, these studies show how project-based production creates barriers by fragmenting workflows, limiting knowledge retention, and discouraging long-term investment in innovation.

2.6.4.3 Complexity/scale of projects

The complexity and scale of construction projects are significant barriers to innovation due to their inherent challenges in coordination, communication, and risk management. Ariono, Wasesa and Dhewanto (2022) note that BIM adoption is more common in large-scale projects in developing countries because these projects offer greater returns on investment and improved efficiency, while smaller projects often fail to justify the costs and efforts associated with BIM implementation. Similarly, Blayse and Manley (2004) emphasise that large and intricate projects present considerable obstacles to efficient communication, resulting in fragmented efforts that hinder innovation.

Nonetheless, it is proposed that integrated strategies like design-build or project alliancing can alleviate these challenges by enhancing communication, learning, and innovation throughout the supply chain. Adding on this, Davidson (2013) further highlights that the intrinsic complexity of the building process exacerbates fragmentation within the industry, increasing interfacing challenges among participants and complicating innovation adoption. Lenderink et al. (2020) further argue that the physical scale, complexity, and long lifespan of construction projects impose additional requirements for innovations, making it difficult for firms to recover investments in radical innovations. Collectively, these studies show how the complexity and scale of projects limit collaboration, hinder knowledge transfer, and suppress incentives for innovation.

2.6.4.4 Time constraints

Time constraints are a significant barrier to innovation in the construction industry, primarily due to the pressure to deliver projects within strict deadlines and budgets. Ozorhon, Oral and Demirkesen (2016) highlight that these limitations obstruct the implementation of fresh concepts and the experimentation with novel products or systems, particularly in smaller construction companies, where time constraints lead to a perceived disinterest in innovation. Similarly, Hardie (2010) highlights that the duration needed for testing and developing technological innovations poses a significant obstacle for small and medium-sized enterprises (SMEs). Ratana Singaram et al. (2023) expand on this by emphasising that time constraints also arise from the need for SME contractors to implement Construction 4.0 technologies, such as BIM, which demand additional training and resources, further delaying adoption. Rose, Manley and Widen (2019) add that contractor time pressure inhibits consideration of new product ideas, leading to conservative, risk-averse approaches and discouraging innovation. Additionally, time pressure prevents the sufficient testing of new products by suppliers, leading to client cynicism toward poorly tested innovations. This aligns with Wei and Lam (2014) who emphasise that short project timelines leave little room for innovation, with the risk of late delivery ranked as a critical barrier. Collectively, these studies show how tight schedules and short-term planning horizons suppress innovation by limiting experimentation, reducing risk tolerance, and discouraging long-term investment in new technologies.

2.6.5 External and Systematic Barriers

2.6.5.1 Industry fragmentation

The division within the industry poses a major obstacle to innovation in the construction field, mainly because of its fragmented organisation and the lack of efficient collaboration. Akintoye, Goulding and Zawdie (2012) highlight that the fragmented nature of the industry restricts knowledge sharing, impedes innovation, and negatively impacts project efficiency. This fragmentation arises from the separation of design and construction processes, which are often performed by different entities at different stages, leading to limited interaction and coordination among stakeholders. Blayse and Manley (2004) describe these temporary coalitions of firms as "loose couplings," which, while fostering project-specific innovation, often fail to codify learnings, leading to lost opportunities for cumulative knowledge development. Tatum (1986) emphasises that fragmentation limits resources available to individual firms for innovation and creates inertia by focusing on practical matters rather than systemic technological advancement. Similarly, Rose, Manley and Widen (2019) further identify the fragmented multi-firm production model as a key barrier to innovation, resulting in disjointed relationships across project networks and hindering systematic capture of innovation opportunities. Collectively, these studies show how fragmentation disrupts communication, inhibits knowledge transfer, discourages investment in innovation, and perpetuates inefficiencies across the construction industry.

2.6.5.2 Risk of failure

Risk of failure is a significant barrier to innovation in the construction industry, particularly in the adoption of technologies like Building Information Modeling (BIM). Ariono, Wasesa and Dhewanto (2022) highlight that risk aversion is a prevailing barrier in developing countries, where industry players are concerned about the uncertainty of achieving significant business returns from BIM implementation. Similarly, Gambatese and Hallowell (2011) note that less successful firms tend to avoid investments in untested ideas, reflecting a conservative approach driven by fear of failure. Giel and Issa (2013) expand on this by emphasising that high initial costs and uncertainty surrounding BIM's benefits deter professionals from adopting the technology. This financial risk aversion creates a cycle where firms prioritize traditional methods over innovative solutions. Rose, Manley and Widen (2019) identify disagreements between clients and suppliers over who should bear the risk of new product failure as another significant obstacle. These disputes often result in stalled adoption of new technologies and perpetuate risk-averse attitudes within the industry. In addition, Wei and Lam (2014) argue that risk aversion is exacerbated by traditional contracts, which intensify risk conditions for contractors and discourage innovation due to fears of late delivery or project failure. Arayici, Khosrowshahi, Farzad Ponting and Mihindu (2009) add that many UK construction companies perceive BIM’s benefits as insufficient to outweigh its implementation costs, further reinforcing risk-averse attitudes. Collectively, these studies show how risk aversion limits experimentation and innovation in construction projects.

2.6.5.3 Inappropriate legislation

Inappropriate legislation has been consistently identified as a major barrier to Building Information Modeling (BIM) adoption, particularly in developing countries. Arayici, Khosrowshahi, Farzad Ponting and Mihindu (2009) emphasise that outdated legal and compensation schemes hinder knowledge sharing and collaboration, which are essential for BIM implementation. Similarly, Ariono, Wasesa and Dhewanto (2022) highlight the lack of mandatory government policies requiring BIM adoption in private projects in Malaysia, resulting in limited innovation from the private sector. Olatunji (2011) elaborates on the fragmented nature of existing legal frameworks in AECO industries, which fail to address modern contractual risks associated with e-business and BIM processes. Key legal challenges include model ownership, jurisdictional ambiguities in e-contracts, and obligations regarding professional responsibilities and errors. These issues create uncertainty and discourage firms from adopting BIM due to fears of legal repercussions. Wei and Lam (2014) further note that stringent regulations often discourage innovation by favouring traditional methods over ambitious standards that could drive demand for innovative solutions. Collectively, these studies highlight the need for reforming legal frameworks to align with digital advancements, including creating BIM-specific standards, enforcing government mandates, and fostering collaboration to overcome legislative barriers to innovation.

2.6.5.4 Procurement systems (e.g., lump-sum contracts)

Traditional procurement systems, particularly lump-sum contracts, are widely recognised as barriers to innovation in the construction industry due to their emphasis on competition based solely on price. Blayse and Manley (2004) highlight that these contracts discourage contractors from adopting novel processes and technologies, as the high-cost risks and adversarial relationships they foster make innovation financially unattractive. This price-driven approach often overlooks critical factors such as experience, skill, and safety records, leading to under-resourced design phases and suboptimal project outcomes, as noted by Hardie (2010). Wei and Lam (2014) further argue that clients' preference for speed and cost alone undermines the value of innovative solutions, reinforcing a short-term mindset that suppresses collaboration and experimentation. Collectively, these studies emphasise that traditional procurement methods like lump-sum contracts inhibit collaboration, integration, and long-term innovation.

2.6.5.5 Economic/political conditions

Economic and political conditions are significant barriers to innovation in the construction industry, particularly in developing countries. Ariono, Wasesa and Dhewanto (2022) highlight that high costs for BIM implementation, inadequate incentives, and limited familiarity with advanced technologies hinder innovation. Additionally, many developing nations lack mandatory government policies requiring BIM adoption, resulting in slow progress in private-sector projects. Similarly, Oladapo (2007) identifies the high cost of ICT software and hardware, rapid obsolescence of technology, and low job orders as economic constraints that discourage investment in innovation. Politically, insufficient government support and unreliable infrastructure, such as irregular power supply, further exacerbate these challenges. While Oladapo notes that external factors like political and economic conditions indirectly influence ICT adoption, internal factors such as managerial perceptions and technical know-how are more significant determinants. Collectively, these studies emphasise that economic barriers like high implementation costs and political barriers such as inadequate policies and infrastructure create substantial obstacles to innovation in the construction sector.

2.7 Summary of Barriers of Innovation

Tables 2.7 and 2.8 below provide a summary of the barriers that hinder innovation, as identified in the literature review.

Note to Table 2.7

Authors: [A] is Akintoye, Goulding, and Zawdie (2012), [B] is Arayici, Khosrowshahi, Farzad Ponting, and Mihindu (2009), [C] is Ariono, Wasesa, and Dhewanto (2022), [D] is Blayse and Manley (2004), [E] is Coates et al. (2010), [F] is Davidson (2013), [G] is Gambatese and Hallowell (2011), [H] is Giel and Issa (2013), [I] is Gong and Wang (2021), [J] is Hardie (2010), [K] is Lenderink, Halman, and Voordijk (2020), [L] is Maghsoudi, Duffield, and Wilson (2016), [M] is Meng and Brown (2018), [N] is Oladapo (2007), [O] is Olatunji (2011), [P] is Owolabi et al. (2019), [Q] is Ozorhon, Oral, and Demirkesen (2016), [R] is Ratana Singaram et al. (2023), [S] is Rose, Manley, and Widen (2019), [T] is Shabenesfahani (2012), [U] is Tajuddin, Iberahim, and Ismail (2015), [V] is Tan et al. (2019), [W] is Tatum (1986), [X] is Tatum (1989), [Y] is Wang, Adetola, and Abdul-Rahman (2015), [Z] is Webb (1981), and [AA] is Wei and Lam (2014).

Table 2.7: Literature Map for Barriers.

Ref	Barriers	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
	Organisational Challenges																											
1	Unsupportive organisational culture		✓	✓														✓						✓				✓
2	Fear of change		✓					✓									✓											
3	Lack of incentives			✓																✓				✓				
4	Organisational rigidity							✓													✓				✓			
5	Lack of recognition from clients				✓			✓																				✓

Table 2.7 (Continued)

Ref	Barriers	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
	Financial and Resouce Limitations																											
6	Lack of financial resource			✓	✓					✓							✓	✓	✓									✓
7	Operational resource gap									✓				✓				✓										
8	Preference for quick pay-off opportunities	✓																							✓			

Table 2.7 (Continued)

Ref	Barriers	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
	Technical and Knowledge Gaps																											
9	Limited innovation knowledge			✓				✓				✓					✓	✓		✓	✓		✓			✓	✓	
10	Lack of experienced and qualified staff			✓														✓		✓						✓		
11	Lack of technical capabilities		✓																		✓		✓			✓		

Table 2.7 (Continued)

Ref	Barriers	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
	Project-Specific and Structural Constraints																											
12	Project-based production	✓		✓	✓		✓				✓	✓								✓								✓
13	Temporary nature of projects	✓			✓		✓				✓		✓					✓				✓						✓
14	Time constraints										✓							✓	✓	✓								✓
15	Complexity/scale of projects			✓	✓		✓					✓																

Table 2.7 (Continued)

Ref	Barriers	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
	External and Systemic Barriers																											
16	Risk of failure		✓	✓				✓	✓											✓								✓
17	Inappropriate legislation		✓	✓												✓												✓
18	Industry fragmentation	✓						✓												✓				✓				
19	Procurement systems (e.g., lump-sum contracts)				✓						✓																	✓
20	Economic/political conditions			✓											✓													

Table 2.8: Final Summary of Barriers of Innovations.

Theme	Barriers	Total Frequency
Organisational Challenges	Unsupportive organisational culture	5
	Fear of change	3
	Lack of incentives	3
	Organisational rigidity	3
	Lack of recognition from clients	3
Financial and Resource Limitations	Lack of financial resource	7
	Operational resource gap	3
	Preference for quick pay-off opportunities	2
Technical and Knowledge Gaps	Limited innovation knowledge	10
	Lack of experienced and qualified staff	4
	Lack of technical capabilities	4
Project-Specific and Structural Constraints	Project-based production	8
	Temporary nature of projects	8
	Time constraints	5
	Complexity/scale of projects	4
	Risk of failure	6
External and Systemic Barriers	Inappropriate legislation	4
	Industry fragmentation	4
	Procurement systems (e.g., lump-sum contracts)	3
	Economical/political conditions	2

2.8 Summary

This chapter delivers an in-depth overview of current literature on construction innovation, concentrating on principal concepts, drivers, and barriers. It scrutinises the varied definitions of innovation within the construction sector, underscoring its importance and the range of interpretations present in the literature. The chapter further investigates notable construction innovations realised in Malaysia, offering a perspective on the country's innovation landscape.

Additionally, the chapter identifies and analyses both the drivers and barriers to innovation as highlighted by earlier research, as depicted in Figure 2.1. Grasping these factors is essential for understanding how innovative approaches are adopted and integrated within the construction industry. The drivers of innovation are systematically grouped into five categories: organisational culture and leadership; collaboration and coordination; market and client demands; technological advancement and innovation processes; and financial, regulatory, and sustainability support. Likewise, the barriers to innovation are classified under five headings: organisational difficulties; financial and resource constraints; technical and knowledge shortfalls; project-specific and structural limitations; and external or systemic obstacles.

By synthesising these insights, the chapter establishes a foundation for more detailed examination and research into the drivers and barriers influencing innovation in Malaysia's construction industry.

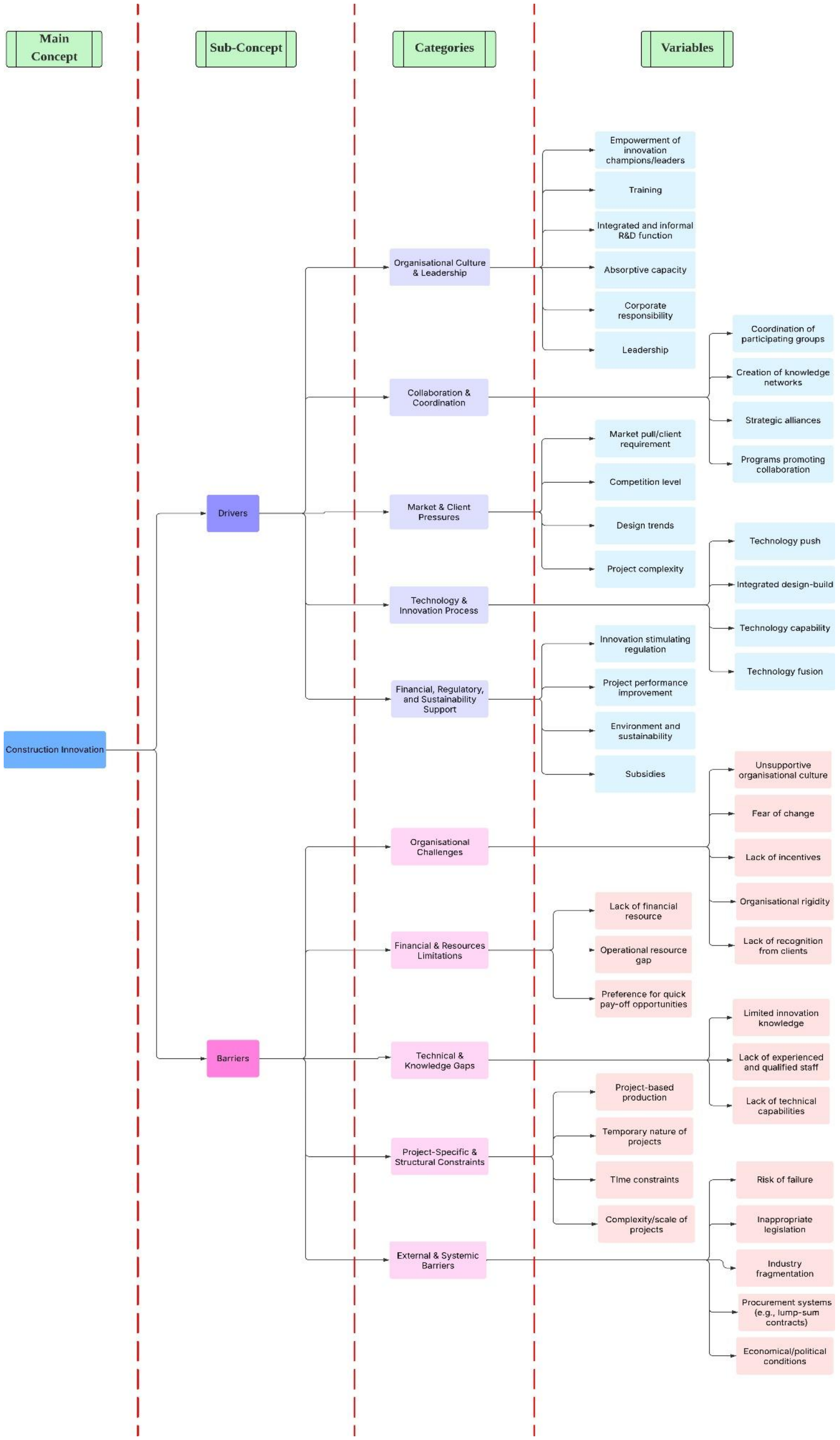

Figure 2.1: Conceptual Framework of Drivers and Barriers of Construction Innovation.

CHAPTER 3

METHODOLOGY AND WORK PLAN

3.1 Introduction

This chapter primarily concentrates on the systematic methodologies utilised to carry out this research. Through the application of rigorous scientific analysis and techniques to the gathered data, the study seeks to uncover underlying insights that might not be immediately evident. Accordingly, this chapter outlines the selected research approach, including the research framework, sampling strategy, data collection methods, and data analysis procedures.

3.2 Research Methodology

This research adopts the "Research Onion" framework by Saunders, Lewis and Thornhill (2009, p. 131) to visually represent the methodology employed in this study, as illustrated in Figure 3.1. Grounded in pragmatism, the study begins with the identification of a problem and aims to offer practical solutions that can inform future practice. A deductive approach is employed alongside a quantitative methodology to systematically address the research questions. The research strategy involves using a questionnaire survey as the sole data collection method, thus constituting a mono-method approach. The study is designed as a cross-sectional survey, gathering data at a single point in time to provide a snapshot of the current drivers and barriers affecting construction innovation in Malaysia. This structured approach ensures that the data collected is standardised and suitable for statistical analysis, thereby enabling the testing of hypotheses and the extraction of meaningful conclusions.

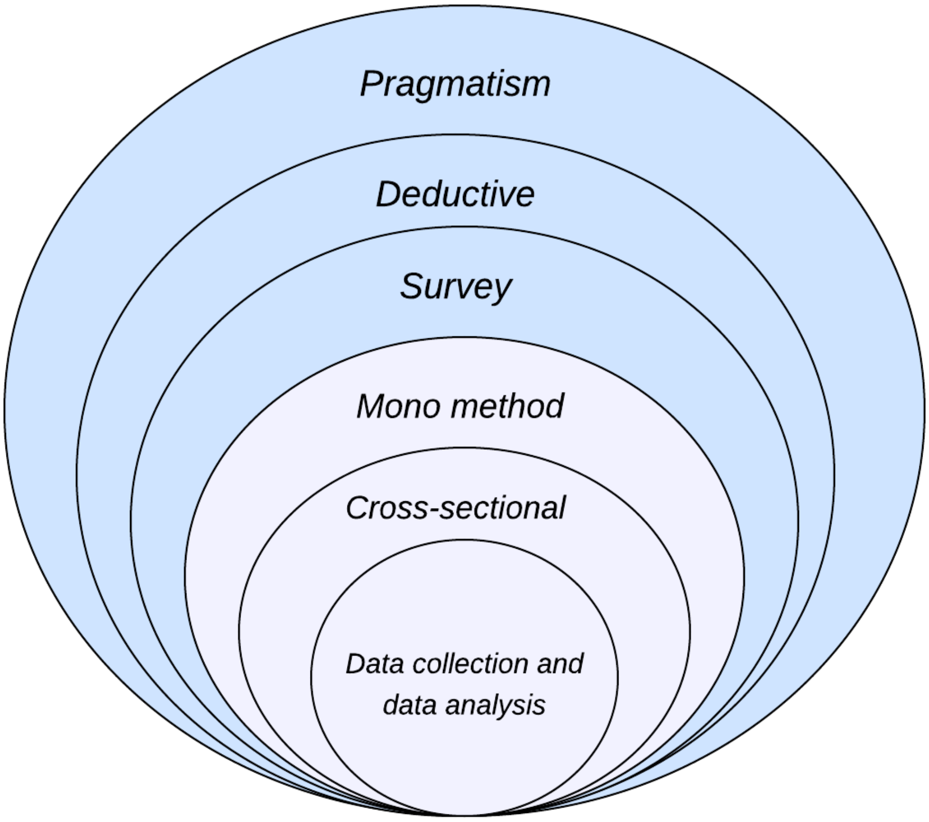

Figure 3.1: Research Onion Framework, adapted from Saunders, Lewis and Thornhill (2009).

3.3 Research Strategy

In research, two primary strategies are commonly employed: qualitative research and quantitative research. Qualitative research focuses on comprehending complex realities and the meanings behind actions within specific contexts. It prioritises in-depth insights over numerical representation, allowing researchers to explore the nuances of human behaviour and contextual factors (Queirós, Faria and Almeida, 2017). In contrast, quantitative research emphasises objectivity and precision, utilising statistical analysis to measure and analyse quantifiable data. This approach is particularly effective for generating reliable and generalisable findings from population samples (Apuke, 2017; Queirós, Faria and Almeida, 2017).

According to Saunders, Lewis and Thornhill (2009), the deductive process in quantitative research requires translating abstract concepts into measurable variables to enable empirical assessment. This characteristic makes quantitative methods ideal for studies with clearly defined research problems. Given the nature of this study, quantitative research was deemed appropriate. Its structured approach facilitates efficient data collection and analysis, ensuring reliable insights into a well-defined problem. By employing this methodology, the study aims to provide robust evidence that contributes to understanding innovation dynamics within Malaysia's construction industry.

3.4 Research Design

The research design of this study employs a systematic approach, as depicted in Figure 3.2, to investigate the research problem. The research flow is divided into four key phases: Conceptualisation, Exploration, Data Collection and Analysis, and Synthesis.

The Conceptualisation phase establishes a solid foundation for the study, beginning with the formulation of a research direction to define the broad area of interest. This is followed by the formulation of a problem statement to articulate the specific issue, advancing to the identification of a research gap through a review of existing literature. This process leads to the establishment of the research aim and objectives, providing clear goals and direction.

The Exploration phase gathers existing knowledge and identifies key elements through a comprehensive literature review, enabling an understanding of current research, theories, and methodologies, which aids in the identification of key variables to be studied in this research.

The Data Collection and Analysis phase involves empirical work. Data is collected through quantitative methods using questionnaire surveys and subjected to rigorous data analysis using statistical techniques, including reliability test, normality test, mean ranking, hypothesis test, and factor analysis.

Finally, the Synthesis phase integrates all findings to generate comprehensive insights by summarising insights, identifying research limitations, and determining potential factors specific to the Malaysian context.

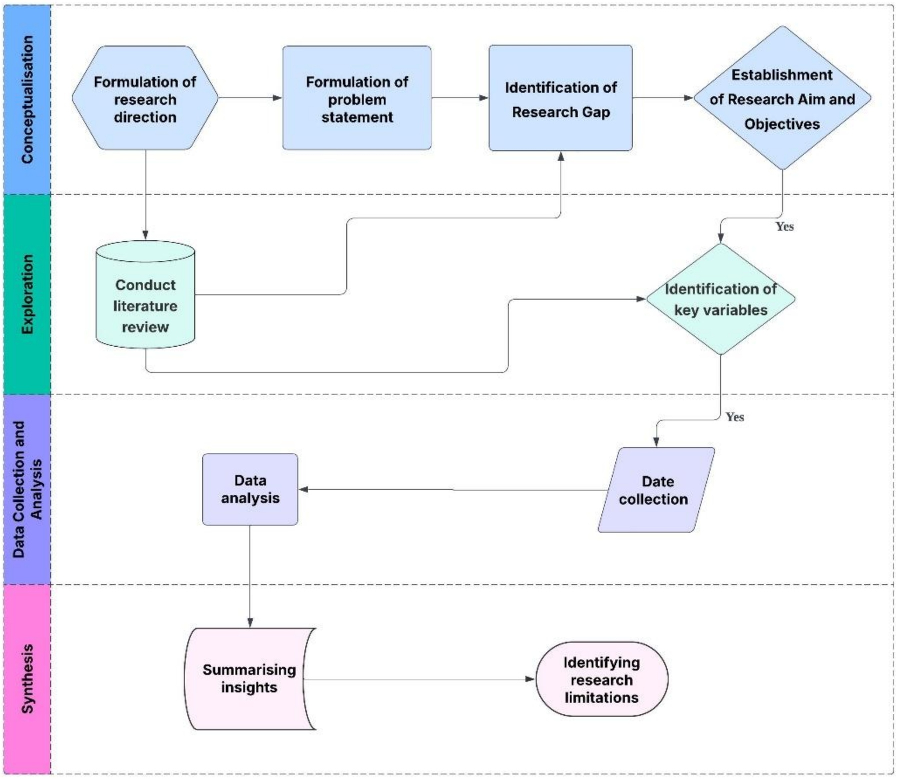

Figure 3.2: Research Flowchart.

3.5 Sampling Design

Before data collection, a structured sampling design was developed to ensure the selection of a representative sample from the target population. According to Sharma (2023), sampling design is a systematic plan for acquiring a sample, frequently outlined in mathematical terms to establish the likelihood of selecting a particular sample. It incorporates the methods and processes utilised by researchers to choose elements for inclusion, ensuring the sample faithfully mirrors the characteristics of the studied population. The main aim of sampling design is to reduce discrepancies between sample and population values, while accounting for constraints like budget and time (Kumar, 2011, p. 20).

Given the impracticality of collecting data from the entire population due to logistical and resource limitations, sampling design plays a pivotal role in research. By carefully defining the sampling method, identifying target respondents, and calculating an appropriate sample size, researchers can ensure reliability and validity in their findings. In this study, the sampling design was meticulously crafted to select respondents who adequately represented the population, thereby enhancing the credibility of the research outcomes.

3.5.1 Sampling method

Quantitative research may employ either probability or non-probability sampling techniques, whilst qualitative research is limited to non-probability sampling techniques (Berndt, 2020). This study utilises a combination of non-probability sampling methods, including judgmental sampling, convenience sampling, and snowball sampling. Non-probability sampling entails selecting participants based on specific criteria rather than random chance, enabling targeted data collection (Etikan, 2017). Judgmental sampling was implemented to deliberately select participants based on their expertise or relevance to the research topic, utilising the researcher's judgment to ensure the sample represents key perspectives. This approach is particularly appropriate when seeking uniquely informative respondents, accessing specialised populations, or identifying specific types of respondents for in-depth investigation (Adeoye, 2023). Convenience sampling was employed to gather data from readily accessible participants, which improved efficiency and cost-effectiveness by focusing on easily available respondents. This method involves selecting individuals based on factors such as ease of access and geographical proximity (Adeoye, 2023). Additionally, snowball sampling was utilised to reach participants who might otherwise be difficult to access, leveraging existing networks to expand the sample size. This technique effectively identifies respondents within a network, with the crucial feature being that each person is connected with another through direct or indirect linkages (Etikan, 2017). This multi-method approach facilitated a diverse and relevant sample, although it may introduce biases due to the non-random selection process. To mitigate these limitations, efforts were made to validate findings against existing literature.

3.5.2 Target respondents

In this study, the target population consists of key construction professionals operating within the Klang Valley, a region also known as Greater Kuala Lumpur as described by Yap and Chow (2020). The Klang Valley encompasses the principal urban centres of Selangor and is recognised as the driving force behind Malaysia’s economic expansion. This area is particularly notable for its dense concentration of construction activities, making it highly relevant for research into construction innovation. Recent data from the Department of Statistics Malaysia (2025a) indicates that Selangor recorded the nation’s highest value of completed construction work at RM9.4 billion (22.5%), primarily attributed to non-residential and residential buildings as well as civil engineering projects. This underscores the strategic importance of the Klang Valley for examining trends and practices in construction innovation.

The intended respondents for this research include clients, consultants, and contractors who are actively involved in construction projects throughout the Klang Valley. Their varied professional backgrounds ensure a comprehensive representation of the different segments within the construction industry. Participants were selected based on their active engagement in construction-related activities and their knowledge of current and innovative construction methods. Their perspectives are expected to yield valuable insights, contributing to a thorough understanding of industry practices, challenges, and opportunities in this pivotal region. Thus, the decision to focus on this population is both pragmatic and significant for fulfilling the aims of the research.

3.5.3 Sampling size

Determining the appropriate sample size for this study involved careful consideration of several factors to ensure reliable and meaningful results. One key consideration was the number of variables being analysed. With 22 variables included in this study, the commonly cited "rule of five" recommends having at least five times the number of variables in the sample size, resulting in a minimum of 110 samples (Kyriazos, 2018). This ensures that the analysis can adequately capture relationships and patterns among the variables without overfitting.

Another critical factor was the application of the Central Limit Theorem (CLT), which suggests that a minimum sample size of 30 per category is required to approximate a normal distribution for the sampling distribution of the mean (Kwak and Kim, 2017). Since this study involves three distinct categories, the clients, consultants, and contractors, a total of at least 90 samples would be necessary to meet this criterion. This ensures that statistical tests relying on normality assumptions can be applied effectively.

Additionally, the Raosoft sample size calculator was used to determine the recommended sample size for generalizability. Based on a population of approximately 1.4 million construction practitioners in Malaysia (Siddhartha, 2025), a sample size of at least 384 was suggested for robust generalisation. However, considering a response rate of 30.00%, the actual number of samples required would be reduced to around 115.

Taking these considerations into account, this study aims to collect a minimum of 115 samples from construction practitioners in Klang Valley, Malaysia, as depicted in Figure 3.3. This sample size not only satisfies statistical reliability and generalizability requirements but also ensures comprehensive insights into the perspectives and experiences of construction practitioners across the three categories.

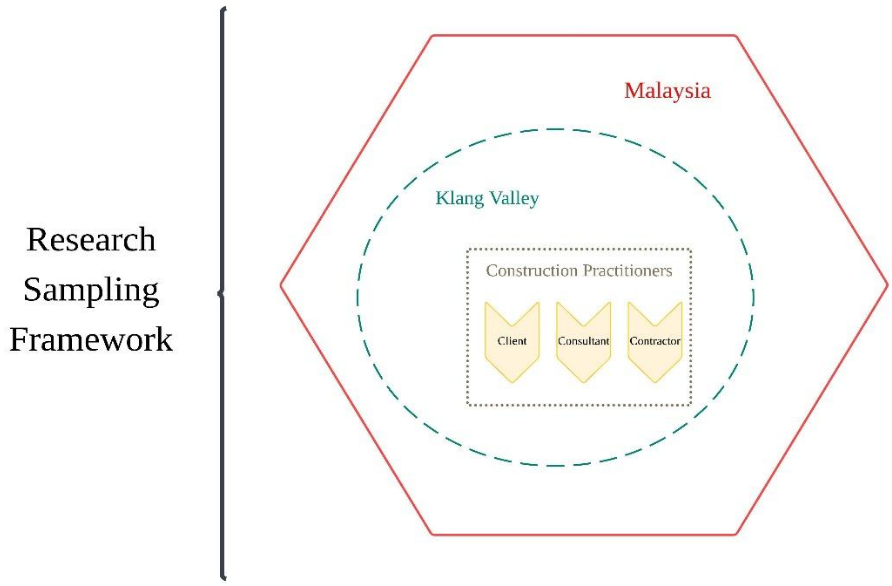

Figure 3.3: Research Sampling Framework.

3.6 Data Collection Method

In research, data is generally classified into two main categories: primary data and secondary data. Primary data refers to information collected directly by the researcher or under their supervision, specifically designed to address the variables of the research question. This type of data is considered original, authentic, reliable, objective, valid, and is typically unpublished prior to the study (Ganesha and Aithal, 2022). In contrast, secondary data is sourced from existing materials such as academic publications, reports, and databases. While secondary data offers a broader context and historical perspective, it may not always be precisely aligned with the specific objectives of the research (Ganesha and Aithal, 2022).

For this study, both primary and secondary data collection methods were utilised to achieve a comprehensive analysis of the drivers and barriers to construction innovation. Primary data was obtained through a structured questionnaire survey distributed to key construction practitioners, including clients, consultants, and contractors operating in the Klang Valley region of Malaysia. This enabled the gathering of first-hand insights directly from professionals actively engaged in construction projects.

Secondary data was gathered by reviewing existing research literature and extracting relevant findings, thereby providing a robust foundation of established knowledge on construction innovation. The integration of both primary and secondary data ensured a well-rounded perspective, supporting informed and reliable conclusions regarding construction innovation within Malaysia’s construction industry.

3.7 Questionnaire Survey Design

The questionnaire utilised in this research is divided into four separate sections, each crafted to gather specific types of information that align with the research objectives.

Section A aims to gather demographic and professional background details of the respondents to ensure the data's relevance and trustworthiness. It includes inquiries about the respondents' roles in the construction industry (i.e., client, consultant, or contractor), their years of experience, academic credentials, and current job titles within their organisations. This information is essential for contextualising the feedback and for analysing how professional background might affect perceptions of innovation drivers and obstacles. In addition to demographic profiling, Section A incorporates a set of introductory attitudinal questions designed to establish respondents’ general orientation toward construction innovation. Specifically, these questions examine whether innovation is considered necessary to meet evolving industry demands and environmental standards, the extent to which innovation has addressed critical project issues such as cost, time, quality, and safety, and the perceived importance of assessing both drivers and barriers to accelerate innovation uptake. Positioned at the outset of the instrument, these items function as a conceptual prelude, framing the relevance of the study and confirming the necessity of systematically investigating the enablers and constraints of innovation within the construction industry.

Section B investigates the respondents' views on various factors that could potentially foster innovation in the Malaysian construction industry. Using a five-point Likert scale that ranges from "Strongly Disagree" to "Strongly Agree," participants are asked to express their level of agreement with a series of statements that reflect possible innovation facilitators. The purpose of this section is to pinpoint key motivators that stimulate innovation from the perspective of industry professionals.

Similar in format to Section B, Section C examines the perceived challenges that impede innovation in the construction sector. Respondents are again prompted to assess their agreement with different potential barriers using a five-point Likert scale. The information collected from this section will provide insight into the limitations and challenges that industry stakeholders believe are driving and obstructing innovation within the context of the Malaysian construction industry.

Finally, Section D seeks to capture forward-looking perspectives regarding the future of construction innovation in Malaysia. Respondents are asked to assess Malaysia’s relative position compared with other countries, the potential impact of innovation on industry competitiveness, and the extent of preparedness within the industry to support innovation over the coming decade. They are further invited to evaluate the likelihood of their organisations allocating greater resources to innovation and the possibility of innovation becoming mainstream practice. By combining perceptual ratings with likelihood-based questions, this section provides a holistic view of industry readiness and anticipated trends.

3.8 Pre-Testing

Pre-testing is a critical phase in survey development, aimed at gathering validity evidence to ensure that the final instrument meets content, cognitive, and usability standards (Carter *et al.*, 2020). In this study, pre-testing was conducted with a purposive sample of six individuals possessing substantial knowledge and experience within the construction industry. The selection of testers was intentionally diverse, encompassing professionals from contracting, consulting, development, and academia, and representing a range of age groups. Specifically, the pre-test panel comprised two clients, two consultants, and two contractors, ensuring that the perspectives of key stakeholder groups were adequately represented. This diversity was designed to confirm that the questionnaire would be comprehensible and relevant to practitioners across different backgrounds and roles within the industry.

The pre-testing process involved the testers reviewing the draft questionnaire and providing detailed feedback on its clarity, relevance, and overall usability. This approach aligns with established best practices, which recommend engaging subject matter experts and representatives of the target population to identify and rectify potential issues related to question wording, ambiguity, and content validity prior to full-scale administration. Based on the feedback received, minor refinements were made to the questionnaire to address ambiguities and enhance clarity, thereby improving the instrument's effectiveness and ensuring it is accessible to a broad spectrum of construction professionals.

3.9 Data Analysis Method

3.9.1 Cronbach's Alpha Reliability Test

Cronbach's alpha (α) is a statistical metric used to assess the internal consistency reliability of a set of items within a questionnaire or instrument. It quantifies the extent to which items measuring the same construct produce consistent responses, thereby indicating the stability and homogeneity of the measurement tool (Bujang, Omar and Baharum, 2018). Values range from 0 to 1, with higher coefficients reflecting greater reliability.

The formula for Cronbach's alpha is shown in equation (3.1) below:

$$\alpha = \frac{N \cdot \bar{c}}{\bar{v} + (N-1) \cdot \bar{c}} \tag{3.1}$$

where
N = the number of items
$\bar{c}$ = average covariance between item-pairs
$\bar{v}$ = average variance

In this study, Cronbach's alpha was employed to evaluate the reliability of the questionnaire survey data collected to address Objective 1 (examining the drivers of construction innovation in Malaysia) and Objective 2 (evaluating the barriers of construction innovation in Malaysia). Each of the scales was required to meet a minimum threshold of $\alpha \geq 0.70$, as recommended by Son, Lee and Kim (2015) for demonstrating adequate internal consistency in exploratory research. Coefficients above this threshold indicate that the items within each domain are strongly interrelated and reliably measure the intended construct. Table 3.1 outlines the interpretative framework for Cronbach's alpha coefficients.

Table 3.1: Cronbach's Alpha Reliability Range.

Cronbach's Alpha Coefficient	Internal Consistency
$\alpha \geq 0.9$	Excellent
$0.9 > \alpha \geq 0.8$	Good
$0.8 > \alpha \geq 0.7$	Acceptable
$0.7 > \alpha \geq 0.6$	Doubtful
$0.6 > \alpha \geq 0.5$	Poor
$\alpha < 0.5$	Not acceptable

3.9.2 Shapiro-Wilk Test

The Shapiro–Wilk test is a widely recognised statistical method for assessing whether a dataset originates from a normally distributed population, and it is particularly effective for small to moderate sample sizes, typically fewer than 50 observations (Mishra *et al.*, 2019). The test assesses the null hypothesis that the data conform to a normal distribution against the alternative hypothesis of non-normality (Choueiry, 2021). The distinguishing feature of this test is its superior statistical power relative to other normality tests, rendering it especially suitable for smaller samples. The test generates a *p*-value, where a value exceeding 0.05 suggests insufficient evidence to reject the null hypothesis, indicating normality. Conversely, a *p*-value below 0.05 leads to rejection of the null hypothesis, signifying a substantial deviation from normality. In this study, a target sample size of 50 respondents per category was employed, making the Shapiro–Wilk test an apt choice due to its robustness and reliability with smaller sample sizes. This approach ensures the verification of normality assumptions necessary for subsequent parametric analyses, thereby strengthening the validity of the research findings.

3.9.3 Ranking of Variables

The drivers and barriers of construction innovation in Malaysia were analysed using the mean score approach, a widely recognised method for ranking relevant variables in construction related research (Wang and Yuan, 2011; Omer *et al.*, 2023; Arogundade, Dulaimi and Ajayi, 2024). Responses were collected through a five-point Likert scale, with values ranging from 1 (least important) to 5 (most important). Higher mean scores indicated that respondents perceived the variable as more significant. In instances where multiple variables shared the same mean score, standard deviation was used as a secondary criterion to differentiate their relative importance, with lower standard deviations reflecting greater consensus and higher criticality (Ye *et al.*, 2015; Babatunde *et al.*, 2020).

This study adopted a mean score threshold of 3.00 as the cut-off point, meaning that any variable scoring 3.00 or above was considered significant (Yap, Lee and Skitmore, 2020). To capture diverse perspectives, mean rankings were conducted separately for each respondent group, the clients, consultants, and contractors, ensuring that the unique viewpoints of each stakeholder category were adequately represented. The results of the mean score analysis was systematically organised in Chapter 4 across three key sections of the questionnaire: general forms of unethical practices, influential factors contributing to these practices, and strategies for prevention. This structured approach facilitated a detailed comparison of perspectives among the different respondent groups, providing a comprehensive understanding of the drivers and barriers to construction innovation in Malaysia.

3.9.4 Kruskal-Wallis Test

The Kruskal-Wallis test is a flexible nonparametric statistical technique used to compare three or more independent samples, serving as a robust alternative to one-way analysis of variance (ANOVA) (Ostertagová, Ostertag and Kováč, 2014). Unlike parametric ANOVA, the Kruskal-Wallis test does not require the assumption of normality, but it does necessitate the independence of observations (Lomuscio, 2021). This makes it particularly valuable when data fail to meet the normality assumptions required by traditional parametric tests, allowing for the effective identification of differences between groups.

In this study, the Kruskal-Wallis test is applied to compare the perspectives of three distinct subgroups: clients, consultants, and contractors. By employing this test, it is possible to determine whether significant differences in the perceptions of the identified drivers and barriers of construction innovation exist among these groups, even in cases where the data distribution is not normal. The Kruskal-Wallis test statistic *H* is calculated using the equation (3.2) below:

$$H = \left[\frac{12}{N(N+1)} \sum_{i=1}^{k} \frac{{R_i}^2}{n_i}\right] - 3(N+1) \qquad (3.2)$$

where

N : Total sample size across all groups

K : Number of groups being compared

n_i : Number of observations in the i-th group

R_i : Sum of ranks for the i-th group

The resulting *H* statistic is compared against a chi-square distribution with $k - 1$ degrees of freedom to determine significance. A significant result would indicate that at least one group differs in its perception of the innovation-related factors, thereby warranting further pairwise comparisons to identify specific group differences. The test assesses two hypotheses. The null hypothesis (H_0) states that there are no significant differences between the groups, implying that any observed differences are likely due to random variation. In contrast, the alternative hypothesis (H_1) posits that at least one group differs significantly from the others, indicating that the observed differences are statistically meaningful and unlikely to be due to chance alone. A significance level of 0.05 is commonly used. If the resulting p-value is less than 0.05 ($p < 0.05$), the null hypothesis is rejected in favour of the alternative, suggesting significant differences exist among the groups. Conversely, if the p-value exceeds 0.05 ($p > 0.05$), the null hypothesis is not rejected, indicating no significant differences between the groups (Ostertagová, Ostertag and Kováč, 2014).

3.9.5 Factor Analysis

Factor analysis is a robust statistical technique designed to simplify complex datasets by condensing a large number of observed variables into a smaller, more manageable set of underlying factors or latent constructs. This method is particularly valuable for revealing patterns and relationships among variables, allowing researchers to identify the fundamental dimensions that underpin observable phenomena (Taherdoost, 2020). By reducing many variables to a few meaningful factors, factor analysis enhances the interpretability of data and supports further statistical procedures, such as regression or multivariate analysis of variance (Shrestha, 2021).

One significant advantage of factor analysis is its ability to address the limitations of ranking methods, which may overlook important factors below the cut-off point. Ranking alone is often insufficient for capturing the complex interrelationships and identifying critical success factors in multifaceted phenomena. For instance, Lu, Shen and Yam (2008) noted that reducing factors solely by ranking is not clean and concise. Similarly, Mom, Tsai and Hsieh (2014) highlighted that ranking analysis may lead to the loss of important factors below the cut-off point, making it inadequate for understanding the characteristics of complex phenomena. Factor analysis overcomes this by uncovering latent structures and relationships, which are crucial for developing robust frameworks to guide performance assessment and decision-making (Mom, Tsai and Hsieh, 2014).

In this study, factor analysis is employed to identify the underlying dimensions that represent the key drivers and barriers to construction innovation. By examining the patterns of correlations among survey items, factor analysis simplifies a large number of variables into a more manageable set of meaningful factors, enhancing interpretability. This technique reveals the latent structures that shape stakeholder perceptions, enabling the study to concentrate on the most significant challenges and enablers related to innovation. The resulting factors yield a clearer understanding of how various elements cluster together, contributing to a more structured and insightful analysis of stakeholder perspectives within the construction industry.

3.10 Summary

Chapter 3 presents a detailed examination of the research methodology and work plan established to explore the drivers and obstacles to construction innovation in Malaysia. The research is based on the "Research Onion" framework by Saunders, Lewis, and Thornhill, which utilises a pragmatic philosophical approach. A deductive strategy is adopted in conjunction with quantitative techniques, employing a mono-method strategy that relies on a questionnaire survey as the main tool for data collection. This survey is organised into four key phases: Conceptualisation, Exploration, Data Collection and Analysis, and Synthesis.

The research employs non-probability sampling techniques, such as judgmental, convenience, and snowball sampling, to reach construction professionals in the Klang Valley region of Malaysia. The minimum required sample size is established at 115 respondents, informed by statistical principles including the "rule of five," Central Limit Theorem, and the Raosoft sample size calculator. The questionnaire is organised into four sections: Section A collects demographic and introductory attitudinal data, Section B evaluates perceptions of innovation drivers, Section C examines barriers to innovation, and Section D explores future prospects, with responses primarily measured using a five-point Likert scale. A pre-test involving industry experts was performed to enhance the clarity and relevance of the questionnaire.

Additionally, this chapter details the data analysis techniques implemented. This includes the Cronbach's Alpha Reliability Test to evaluate the internal consistency of the survey items, ensuring they meet a minimum reliability threshold of $\alpha \geq 0.70$. The Shapiro-Wilk Test assesses the normal distribution of the data. Mean ranking is utilised to order the factors according to their perceived significance. The Kruskal-Wallis Test is applied to compare views among different groups, while factor analysis is implemented to uncover underlying patterns and relationships among the variables. Together, these analytical methods provide a solid framework to accomplish the study's objectives. Figure 3.4 depicts the tests performed to accomplish the specific objectives outlined in this study.

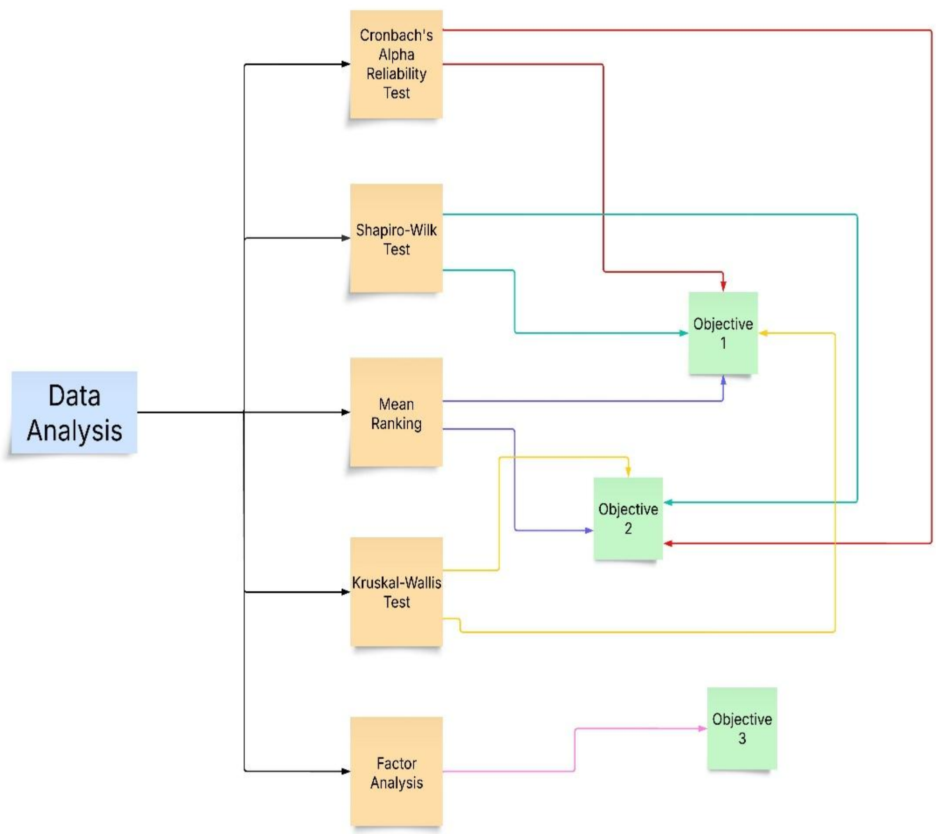

Figure 3.4: Analysis Framework for Achieving Research Objectives.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents and interprets the results obtained from the questionnaire survey. To ensure accuracy and reliability, the data were systematically organised, processed, and tabulated using the Statistical Package for the Social Sciences (SPSS) in conjunction with Microsoft Excel. The findings are analysed and discussed in detail, with the discussion structured to maintain a clear connection to the research objectives and aims outlined in earlier chapters. By doing so, this chapter not only reports the survey outcomes but also provides meaningful insights that contribute to addressing the central research questions.

4.2 Pre-Test

The pre-test survey achieved a full response rate, with input from two clients, two consultants, and two contractors. Their feedback on the questionnaire's clarity, structure, and relevance was used to revise ambiguous wording and address potential misinterpretations before proceeding to the actual survey.

4.3 Response Rate

Following the positive results from the pre-test, the final questionnaire was distributed to the targeted respondents via email and several social media platforms, including WhatsApp, Facebook, and Instagram, to maximise outreach across various organisations. In total, 384 questionnaires were sent to key stakeholders within the Klang Valley region. Over a period of five weeks, 150 completed and valid responses were collected, resulting in a response rate of 39.06%. This surpasses the minimum threshold of 30.00%, which is considered sufficient to ensure the reliability of the findings in relation to the number of free parameters, thus enabling meaningful statistical analysis (Yap, Lee and Skitmore, 2020).

4.4 Responder's Profile

The demographic characteristics of the respondents are summarised in Table 4.1. A total of 150 valid responses were collected, representing stakeholders from different sectors of the construction industry.

In terms of the nature of organisation, the respondents were equally distributed, with one-third representing clients or developers (33.33%), one-third consultants (33.33%), and one-third contractors (33.33%). This balanced distribution ensures that the perspectives obtained are not biased toward a single stakeholder group.

Regarding working experience, the largest proportion of respondents (37.33%) had between 5 and 10 years of industry experience, followed by 28.00% with 11 to 15 years of experience. Respondents with less than 5 years and those with 16 to 20 years of experience each accounted for 15.33%, while only 4.00% had more than 20 years of experience. This indicates that the majority of respondents possess a moderate to high level of practical exposure within the industry.

With respect to position in the company, most of the respondents were executives (60.67%), followed by managers (27.33%) and senior managers (10.00%). Only 2.00% of respondents were from top management or director-level positions. This distribution suggests that the data primarily reflects the views of middle-level professionals actively engaged in operational and managerial functions.

In terms of academic qualification, the majority of respondents (69.33%) held a bachelor's degree, while 12.67% possessed postgraduate qualifications (master's or PhD). A further 12.67% held a diploma, and 5.33% had completed high school education only. This highlights that most respondents are academically well-qualified, which enhances the credibility of the data gathered.

As for the nature of projects undertaken, the majority of respondents (76.67%) were involved in private sector projects, while 23.33% were engaged in public sector projects. In terms of project value range, the largest proportion of respondents (40.00%) reported involvement in projects valued at over RM100 million, followed by 22.67% with experience in projects ranging from RM50 million to RM100 million. A further 14.00% were engaged in projects valued between RM10 million and RM50 million, while another 14.00% participated in projects within the RM1 million to RM10 million range. Only 9.33% indicated experience in projects worth less than RM1 million. These findings suggest that the respondents were predominantly engaged in private sector developments of medium to large-scale value.

Overall, the respondent profile demonstrates a diverse representation in terms of organisational role, experience, position, educational background, and project involvement, thereby ensuring the reliability and generalizability of the research findings.

Table 4.1: Demographic Profile of Respondents.

Parameter	Categories	Frequency	Percentage (%)
Nature of Organisation	Client / Developer	50	33.33
	Consultant	50	33.33
	Contractor	50	33.33
Working Experience	Less Than 5 Years	23	15.33
	5 – 10 Years	56	37.33
	11 – 15 Years	42	28.00
	16 – 20 Years	23	15.33
	Over 20 Years	6	4.00
Position in Company	Executive	91	60.67
	Manager	41	27.33
	Senior Manager	15	10.00
	Top Management / Director	3	2.00
Academic Qualification	High School	8	5.33
	Diploma	19	12.67
	Degree	104	69.33
	Postgraduate (PhD, Master's)	19	12.67
Nature of Project	Public Sector Projects	35	23.33
	Private Sector Projects	115	76.67

Table 4.1 (Continued)

Value Range of Project Involved	Less Than RM1 Million	14	9.33
	RM 1 Million – RM 10 Million	21	14.00
	RM 10 Million – RM 50 Million	21	14.00
	RM 50 Million – RM 100 Million	34	22.67
	Over RM 100 Million	60	40.00

4.5 Respondents' Perceived Relevance and Contribution of the Research

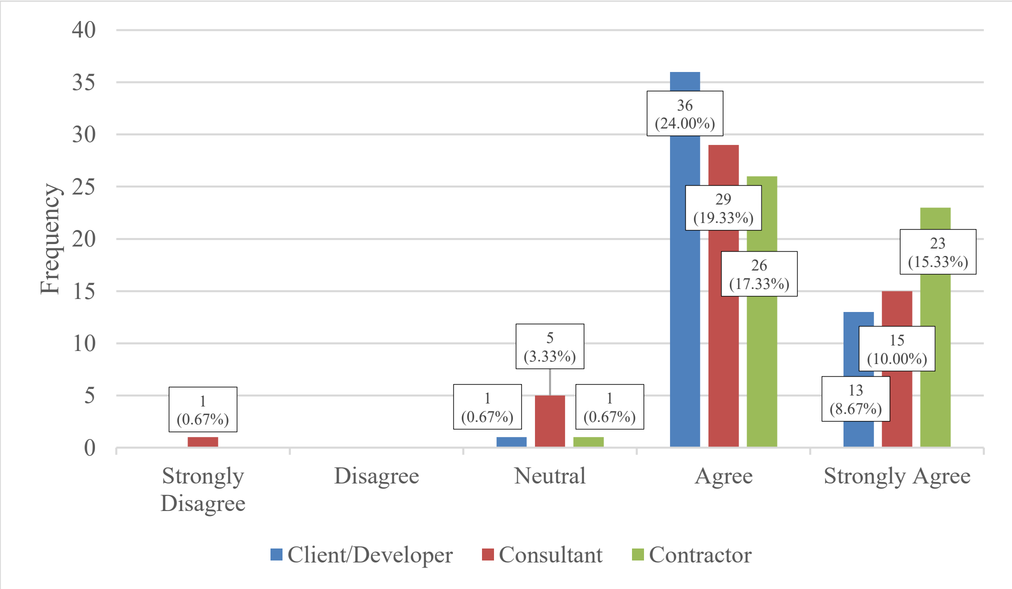

Figure 4.1: Perceived Necessity of Construction Innovation to Meet Industry Demands and Environmental Standards.

Figure 4.1 illustrates the varying perceptions of respondents regarding the necessity of construction innovation to meet industry demands and environmental standards. 94.67% of respondents agreed that construction innovation is necessary to meet evolving industry demands and environmental standards, while 4.67% remained neutral and 0.67% strongly disagreed. These findings underscore the widespread recognition of innovation as a fundamental driver of progress in the Malaysian construction industry.

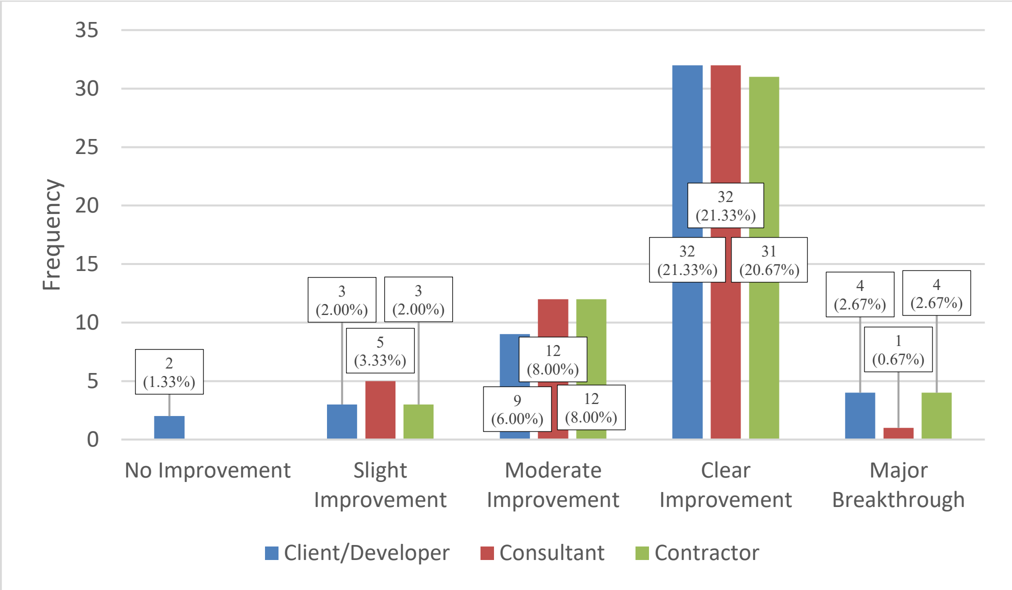

Figure 4.2: Perceptions of Innovation Effectiveness in Addressing Construction Issues.

Figure 4.2 shows a generally positive perception of innovation in addressing construction-related challenges. The data shows that 63.33% of respondents perceived a clear improvement from innovation in addressing construction issues, while 22.00% reported a moderate improvement. This indicates strong confidence in innovation's positive impact. In contrast, only 7.33% reported slight improvement, and 1.33% saw no improvement, reflecting minimal scepticism. Notably, 6.00% of respondents regarded innovation as a major breakthrough, suggesting that while innovation is widely acknowledged as beneficial, it is more commonly perceived as yielding incremental rather than transformative change.

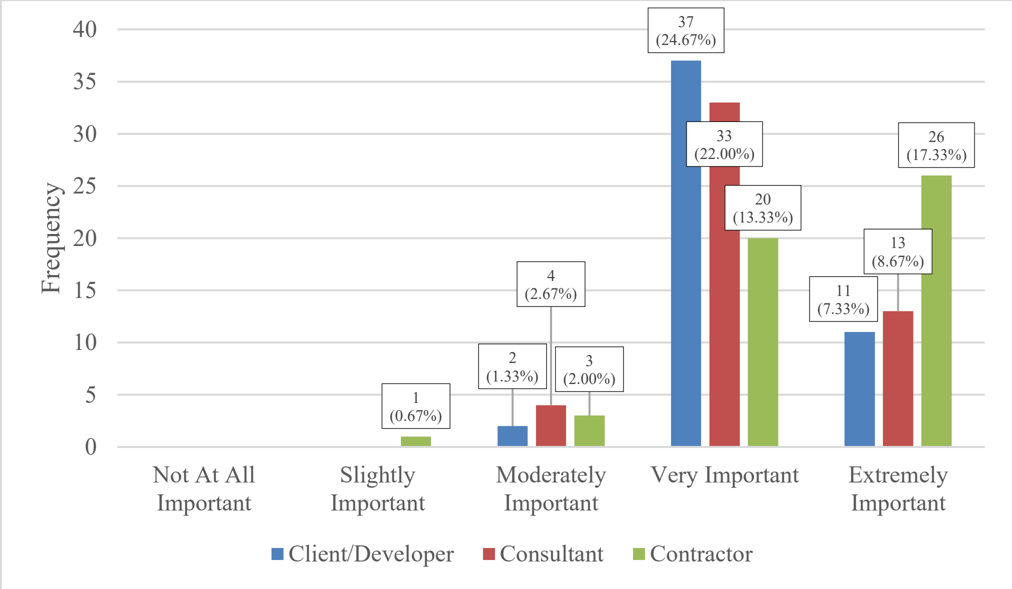

Figure 4.3: Perceptions on the Importance of Assessing Drivers of Construction Innovation.

Figure 4.3 shows a strong recognition of the importance of assessing the drivers of innovation in the construction industry. A majority of respondents rated this as either very important (60.00%) or extremely important (33.33%), indicating widespread agreement on the need to understand what propels innovation. Only a small percentage of participants viewed it as less critical, with 6.00% selecting moderately important, and just 0.67% selecting slightly important. These findings suggest that stakeholders consider the assessment of innovation drivers essential to guiding effective and sustainable innovation within the industry.

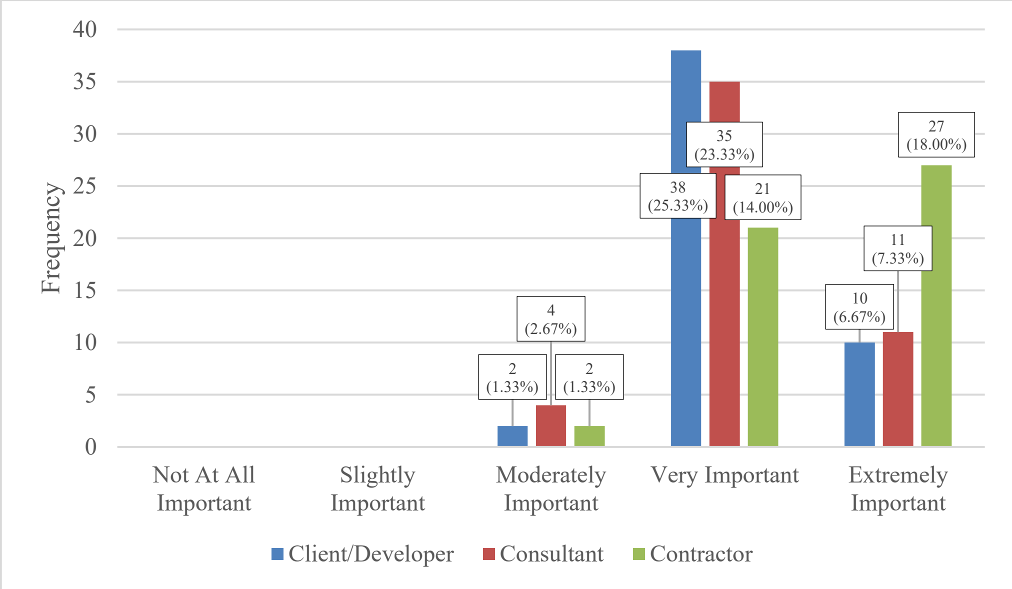

Figure 4.4: Perceptions on the Importance of Assessing Barriers of Construction Innovation.

Figure 4.4 also reflects a strong consensus on the importance of assessing barriers to innovation in the construction industry, similar to the findings on innovation drivers. A majority of respondents rated this as either very important (62.67%) or extremely important (32.00%), reinforcing the widespread agreement on the need to understand both the enablers and the obstacles to innovation. Only 5.33% considered it moderately important, with virtually no indication of lower importance. These findings further suggest that stakeholders view the evaluation of innovation barriers as equally essential to promoting effective and sustainable innovation within the industry.

The generally positive perceptions of innovation effectiveness in addressing construction challenges, alongside the strong acknowledgement of the necessity of construction innovation, underscore the significance of this research. Moreover, the consensus on the importance of assessing both the drivers and barriers of innovation further highlights the critical need to explore these factors in depth. Collectively, these perceptions validate the relevance of this study and provide a solid foundation for a comprehensive investigation into the determinants influencing innovation adoption and success within the construction industry.

4.6 Cronbach's Alpha Reliability Test

To ensure the internal consistency of the measurement items, a reliability test was conducted using Cronbach's Alpha. According to Son, Lee and Kim (2015), a Cronbach's Alpha value of 0.70 or higher is considered acceptable, while values above 0.80 are regarded as good, and values of 0.90 or greater indicate excellent reliability. As presented in Table 4.2, the drivers of construction innovation construct achieved a Cronbach's Alpha value of 0.900, which is classified as excellent. Meanwhile, the barriers to construction innovation construct recorded a value of 0.884, which is considered good. Both values are well above the minimum threshold of 0.70, confirming that the items used to measure these constructs demonstrate strong internal consistency and are reliable for further statistical analysis.

Table 4.2: Summary of Reliability Analysis.

Category of Variables	**Number of Items**	**Alpha Value**	**Reliability Level**
Drivers of Construction Innovation	22	0.900	Excellent
Barriers of Construction Innovation	20	0.884	Good

4.7 Normality Test – Shapiro-Wilk Test

The Shapiro–Wilk test was performed to assess the normality of the data distribution for the constructs of drivers of construction innovation and barriers to construction innovation. The Shapiro–Wilk test is widely recommended for small to medium sample sizes ($n \leq 50$) and provides a robust measure of data normality (Mishra *et al.*, 2019). As shown in Table 4.3 and Table 4.4, the Shapiro–Wilk statistics for both constructs were significant at $p < 0.001$, indicating a deviation from normal distribution. Since these values are below the threshold of 0.05, the null hypothesis of normality is rejected, and it can be concluded that the data for both constructs are not normally distributed. Given these results, non-parametric statistical methods were deemed more appropriate for subsequent analyses. In particular, the Kruskal–Wallis test will be employed to examine differences between groups, as it does not assume normality and is suitable for comparing independent samples across categorical variables.

Table 4.3: Normality Test for Drivers of Construction Innovation.

Ref	Drivers of Construction Innovation	Shapiro-Wilk Sig.	Normality
D1	Empowerment of innovation champions/leaders	< 0.001	Not Normal
D2	Training	< 0.001	Not Normal
D3	Integrated and informal R&D function	< 0.001	Not Normal
D4	Absorptive capacity	< 0.001	Not Normal
D5	Corporate responsibility	< 0.001	Not Normal
D6	Leadership	< 0.001	Not Normal
D7	Coordination of participating groups	< 0.001	Not Normal
D8	Creation of knowledge networks	< 0.001	Not Normal
D9	Strategic alliances	< 0.001	Not Normal
D10	Programs promoting collaboration	< 0.001	Not Normal
D11	Market pull/client requirement	< 0.001	Not Normal
D12	Competition level	< 0.001	Not Normal
D13	Design trends	< 0.001	Not Normal
D14	Project complexity	< 0.001	Not Normal
D15	Technology push	< 0.001	Not Normal
D16	Integrated design-build	< 0.001	Not Normal
D17	Technology capability	< 0.001	Not Normal
D18	Technology fusion	< 0.001	Not Normal
D19	Innovation stimulating regulations	< 0.001	Not Normal
D20	Project performance improvement	< 0.001	Not Normal
D21	Environment and sustainability	< 0.001	Not Normal
D22	Subsidies	< 0.001	Not Normal

Table 4.4: Normality Test for Barriers of Construction Innovation.

Ref	Barriers of Construction Innovation	Shapiro-Wilk Sig.	Normality
B1	Unsupportive organisational culture	< 0.001	Not Normal
B2	Fear of change	< 0.001	Not Normal
B3	Lack of incentives	< 0.001	Not Normal
B4	Organisational rigidity	< 0.001	Not Normal
B5	Lack of recognition from clients	< 0.001	Not Normal
B6	Lack of financial resource	< 0.001	Not Normal
B7	Operational resource gap	< 0.001	Not Normal
B8	Preference for quick pay-off opportunities	< 0.001	Not Normal
B9	Limited innovation knowledge	< 0.001	Not Normal
B10	Lack of experienced and qualified staff	< 0.001	Not Normal
B11	Lack of technical capabilities	< 0.001	Not Normal
B12	Project-based production	< 0.001	Not Normal
B13	Temporary nature of projects	< 0.001	Not Normal
B14	Time constraints	< 0.001	Not Normal
B15	Complexity/scale of projects	< 0.001	Not Normal
B16	Risk of failure	< 0.001	Not Normal
B17	Inappropriate legislation	< 0.001	Not Normal
B18	Industry fragmentation	< 0.001	Not Normal
B19	Procurement systems (e.g., lump-sum contracts)	< 0.001	Not Normal
B20	Economic/political conditions	< 0.001	Not Normal

4.8 Drivers of Construction Innovation in Malaysia

4.8.1 Mean Score and Standard Deviation

The perceived drivers of construction innovation in Malaysia are ranked in accordance with the mean and standard deviation computed as shown in Table 4.5. Overall, the five most critical drivers of construction innovation are:

(i) Technology push (Mean = 4.47, SD = 0.564).
(ii) Environment and sustainability (Mean 4.37, SD = 0.595).
(iii) Technology capability (Mean = 4.35, SD = 0.555).
(iv) Strategic alliances (Mean = 4.29, SD = 0.638).
(v) Subsidies (Mean = 4.27, SD = 0.631).

Technology push is ranked as the most critical driver of construction innovation in this study. Advancements in tools, materials, and processes often precede or complement market demand, creating new opportunities for adoption in the industry. Becerik-Gerber, Gerber and Ku (2011) show how emerging technologies such as BIM, sustainability tools, and virtual learning applications drive adoption and integration into industry practices, particularly in education and project management. Meng and Brown (2018) further frame this within a dual dynamic, where technology-push interacts with competition and client needs to shape innovation. While early work by Nam and Tatum (1992) suggested that technology push could even precede demand-pull forces, more recent studies have reinforced this perspective. For example, Owolabi et al. (2019) identify ICT development as a major driver of innovation in Nigeria, while Ozorhon, Oral and Demirkesen (2016) emphasise that ICT and new materials foster both collaboration and employee skills. Collectively, these studies affirm that technology push continues to fuel construction innovation by introducing transformative solutions, enhancing adaptability, and creating environments where firms and workers refine and implement advancements. In the Malaysian context, this finding highlights the significance of government-led initiatives such as the Construction Industry Transformation Programme (CITP), which has prioritised BIM and IBS adoption (Abdul Rahim and Zakaria, 2017; Mohd Najib *et al.*, 2019). Given that SMEs dominate the industry, a sustained technology push through digital platforms, prefabrication, and automation could be critical for enhancing efficiency and productivity. This suggests that innovation in Malaysia will increasingly depend on the ability of firms to absorb and integrate emerging technologies into their operations.

The second most significant driver identified by respondents is environment and sustainability. Increasing environmental pressures and global sustainability agendas are compelling the construction sector to embrace innovative practices that reduce ecological impacts. Ariono, Wasesa and Dhewanto (2022) highlight how sustainability pressures in developing countries have spurred innovations such as green building standards and smart city initiatives, where BIM supports material management and IoT/Big Data enable informed decision-making. Meng and Brown (2018) similarly identify sustainability as a central driver of innovation, while Ozorhon, Oral and Demirkesen (2016) emphasise that climate change concerns have accelerated innovations in equipment, techniques, and products. More recently, Ozorhon and Oral (2017) further underscored environmental sustainability as a core motivator for construction innovation. Together, these studies demonstrate that sustainability not only drives the adoption of green technologies but also reshapes processes, materials, and project designs, positioning it as a critical force in modernising the industry. This aligns with Malaysia's recent policy direction, particularly the push for net-zero carbon goals and the adoption of the Green Building Index (GBI) (Mohd Najib *et al.*, 2019; Mat Yaman and Abd Ghadas, 2023). The prioritisation of sustainability as a driver in this study suggests that local firms are increasingly recognising innovation as a pathway not only to compliance but also to competitiveness in regional markets. It implies that sustainable innovation could become a differentiator for Malaysian construction firms, especially as international clients demand higher environmental standards.

Technology capability emerges as the third key driver of construction innovation. Firms with strong technological expertise are more capable of adopting and adapting innovative solutions to suit project-specific needs. Bossink (2004) defines technological capability as the technical factors that enable innovation, supported by industry-wide programs, pilot projects, and technology fusion. Nam and Tatum (1992) earlier work challenged the view that innovation is solely demand-driven, arguing instead that technological advancements can proactively shape owner demands and problem-solving approaches. Recent research similarly supports the view that continuous research and development (R&D), strategic leadership, and absorptive capacity are critical enablers that allow firms to leverage their internal capabilities to gain and sustain a competitive advantage (Ozorhon, Abbott and Aouad, 2014; Li, Zhang and Hong, 2020). These findings confirm that technological capability is not merely supportive but actively drives innovation by fostering experimentation and competitiveness within the sector. For Malaysia, this finding indicates that firms must prioritise capability-building initiatives such as digital training, knowledge transfer, and investment in in-house expertise. As the industry is heavily populated by SMEs, technological capability could become the deciding factor between firms that successfully adopt innovation and those that fall behind (Lada *et al.*, 2023). Strengthening capability will therefore be essential for scaling up industry-wide transformation.

Strategic alliances are ranked as the fourth most critical driver. The fragmented nature of the construction industry makes collaboration essential for innovation. Ariono, Wasesa and Dhewanto (2022) identify alliances and long-term relationships as drivers of BIM innovation in developing countries, while Kagioglou et al. (2000) highlight the importance of integrating teams and processes through collaboration involving contractors, clients, and IT specialists. Building on these early insights, recent studies emphasise that alliances remain central to innovation. For example, Bossink (2004) notes their role in sharing risks and leveraging complementary expertise in sustainable construction, and Miozzo and Dewick (2002) underline their importance for accessing external knowledge and operational capacity. Collectively, these findings illustrate that strategic alliances foster innovation by enabling knowledge exchange, risk mitigation, and the integration of diverse expertise across firms. In Malaysia, where supply chains remain fragmented and competitive pressures often discourage collaboration, the emphasis on alliances in this study highlights a pressing need for greater cooperation (Wuni and Shen, 2020; Durdyev *et al.*, 2025). Strategic alliances, particularly between SMEs and larger contractors, could accelerate technology transfer and resource sharing. This finding also suggests that government and industry bodies should promote collaborative procurement models and joint ventures to maximise innovation outcomes.

Lastly, subsidies are identified as the fifth critical driver of innovation. Financial incentives reduce risks and encourage firms to invest in advanced technologies that might otherwise be too costly to implement. Bossink (2004) illustrates how subsidies for sustainable applications and materials have been integrated into project requirements, while Gong and Wang (2022) highlight that subsidies complement firms' R&D investment by signalling credibility to private investors and reducing financial barriers. Similarly, Ozorhon and Oral (2017) show how government programs and research grants reward innovators while lowering perceived risks, creating an enabling environment for experimentation. However, Wang, Lin and Li (2019) caution that subsidies are most effective in the early stages of industry development and may produce diminishing returns if overused. Collectively, these findings suggest that subsidies remain a critical policy instrument for stimulating innovation, particularly in sustainable practices and R&D, though their long-term impact depends on strategic and targeted implementation (Song *et al.*, 2022). In Malaysia, this highlights the importance of maintaining but refining government support mechanisms such as R&D grants, green technology financing schemes, and tax incentives. However, subsidies should be targeted at SMEs that lack financial capacity, ensuring that innovation is not concentrated among larger firms alone. This study therefore suggests that policy design must evolve to balance short-term support with long-term sustainability of innovation.

Table 4.5: Mean Score and Standard Deviation of Drivers of Construction Innoovation in Malaysia.

Ref	Drivers of Construction Innovation	Overall (N=150)			Client/Developer (N=50)			Consultant (N=50)			Contractor (N=50)			Chi-square	Asymp. sig
		Mean	SD	R	Mean	SD	R	Mean	SD	R	Mean	SD	R		
Organisational Culture & Leadership															
D1	Empowerment of innovation champions/leaders	3.89	0.657	22	3.90	0.580	20	3.84	0.710	22	3.94	0.682	22	0.646	0.724
D2	Training	4.24	0.610	7	4.14	0.572	9	4.12	0.627	9	4.46	0.579	6	10.073	0.006**
D3	Integrated and informal R&D function	4.23	0.680	8	4.20	0.700	6	4.02	0.685	17	4.48	0.580	3	11.379	0.003**
D4	Absorptive capacity	4.19	0.649	9	4.04	0.605	18	4.12	0.689	10	4.40	0.606	7	8.669	0.013*
D5	Corporate responsibility	4.05	0.731	19	4.08	0.665	14	4.08	0.695	13	4.00	0.833	20	0.140	0.932
D6	Leadership	4.07	0.646	16	4.08	0.665	13	4.02	0.622	16	4.12	0.659	17	0.636	0.728
Collaboration and Coordination															
D7	Coordination of participating groups	4.12	0.623	14	4.22	0.582	4	4.00	0.639	20	4.14	0.639	15	3.067	0.216
D8	Creation of knowledge networks	4.25	0.567	6	4.24	0.591	2	4.26	0.527	6	4.24	0.591	10	0.011	0.995
D9	Strategic alliances	4.29	0.638	4	4.18	0.629	7	4.28	0.640	4	4.40	0.639	8	3.226	0.199
D10	Programs promoting collaboration	3.92	0.690	21	3.84	0.681	22	3.98	0.589	21	3.94	0.793	21	1.514	0.469

Table 4.5 (Continued)

Market and Client Pressures														
D11	Market pull/client requirement	4.06	0.678	18	4.06	0.586	16	4.00	0.639	19	4.12	0.799	16	1.592	0.451
D12	Competition level	3.99	0.608	20	3.90	0.544	21	4.02	0.553	18	4.06	0.712	19	1.864	0.394
D13	Design trends	4.07	0.636	17	4.10	0.614	12	4.04	0.605	15	4.08	0.695	18	0.246	0.884
D14	Project complexity	4.17	0.642	11	4.06	0.620	15	4.26	0.600	7	4.20	0.700	14	2.605	0.272
Technology and Innovation Process														
D15	Technology push	4.47	0.564	1	4.30	0.544	1	4.44	0.577	1	4.68	0.513	1	12.594	0.002**
D16	Integrated design-build	4.19	0.617	10	4.04	0.638	17	4.28	0.536	5	4.24	0.657	11	4.057	0.132
D17	Technology capability	4.35	0.555	3	4.22	0.465	3	4.34	0.593	3	4.48	0.580	5	6.505	0.039*
D18	Technology fusion	4.10	0.632	15	3.96	0.570	19	4.06	0.586	14	4.28	0.701	9	7.242	0.027*
Financial, Regulatory, & Sustainability Support														
D19	Innovation stimulating regulations	4.15	0.588	12	4.19	0.548	8	4.08	0.634	12	4.22	0.582	12	1.305	0.521
D20	Project performance improvement	4.14	0.635	13	4.12	0.558	10	4.10	0.707	11	4.20	0.639	13	0.683	0.711
D21	Environment and sustainability	4.37	0.595	2	4.20	0.639	5	4.42	0.538	2	4.48	0.580	4	5.536	0.063
D22	Subsidies	4.27	0.631	5	4.10	0.647	11	4.18	0.629	8	4.52	0.544	2	12.314	0.002**

N = Sample size, SD = Standard Deviation

Note:
**. The mean difference is statistically significant at the 0.01 level ($p < 0.01$).
*. The mean difference is statistically significant at the 0.05 level ($p < 0.05$).

4.8.2 Kruskal-Wallis H Test

As presented in Table 4.5, the Kruskal–Wallis test shows that out of 22 identified drivers, seven factors demonstrated statistically significant differences in perceptions among clients or developers, consultants, and contractors at the 95% confidence level. These drivers are training ($p = 0.006$), integrated and informal R&D function ($p = 0.003$), absorptive capacity ($p = 0.013$), technology push ($p = 0.002$), technology capability ($p = 0.039$), technology fusion ($p = 0.027$), and subsidies ($p = 0.002$). While each strategy attracted varying levels of support, the results can be better understood by examining thematic patterns across stakeholders rather than treating them as isolated rankings.

Training and absorptive capacity were consistently rated higher by contractors (Mean = 4.46 and 4.40, respectively) than by other groups, reflecting their direct involvement in project execution and the reliance on workforce competence to operationalise innovation. This is further supported by the mean rank positions, where contractors assigned training and absorptive capacity mean ranks of 6 and 7, respectively, which are notably higher than the ranks assigned by clients (Mean Rank 9 and 18, respectively) and by consultants (Mean Rank 9 and 10, respectively). Such ranking disparities elucidate the greater emphasis contractors place on these drivers, underscoring their critical operational roles. This finding supports Coates et al. (2010), who highlight training as a critical enabler for BIM adoption, and align with Owolabi et al. (2019), who argue that absorptive capacity determines how firms internalise external knowledge. In contrast, developers and consultants ranked these factors lower, indicating a tendency to view innovation less as an operational requirement and more through financial or advisory perspectives.

Similarly, contractors placed stronger emphasis on R&D investment (Mean = 4.48) compared with developers and consultants. This is reflected in the mean rank positions, where contractors assigned R&D investment a mean rank of 3, which is notably higher than clients' mean rank of 6 and consultants' mean rank of 17. This may be explained by their position at the operational frontier of construction projects, where the benefits of applied research are most visible. Previous studies have noted that contractors often rely on R&D-driven improvements in productivity and construction methods, whereas developers tend to be more concerned with financial outcomes than with technological experimentation (Manley, 2008).

The divergence is also evident in perceptions of subsidies. Contractors ranked subsidies significantly higher (Mean = 4.52) and assigned it a mean rank of 2, suggesting their stronger dependence on external support to overcome high innovation costs. Developers and consultants assigned subsidies lower mean ranks of 11 and 8, respectively, reflecting their comparatively greater access to capital. This resonates with findings by Gong and Wang (2022), who show that subsidies are particularly critical for SMEs in construction, where financial constraints present a major adoption barrier.

The Kruskal–Wallis test further highlighted group differences in perceptions of technology-related drivers. For technology push, all groups consistently ranked it as the most important driver of construction innovation (Mean Rank = 1), simultaneously indicating consensus on its primacy. However, the mean scores reveal varying intensities of perception: Contractors rated it highest (Mean = 4.68), followed by consultants (Mean = 4.44) and clients/developers (Mean = 4.30). This suggests that, while there is consensus on its primacy, contractors view technological advancement as more critical compared to clients and consultants. Importantly, agreement on ranking does not imply identical perceptions of magnitude. As Field (2015) and McKight and Najab (2010) emphasise, the Kruskal–Wallis test evaluates differences in the distribution of ranks across groups, rather than simple orderings. Thus, significance arises not because groups disagree on the “top driver,” but because they differ in how strongly they perceive its importance. From a practical perspective, this suggests that contractors, being directly engaged in construction delivery, may experience greater pressure to adopt and integrate new technologies compared to clients or consultants, who may prioritise broader strategic or advisory concerns. This finding supports prior research indicating that technology adoption pressures are most acutely felt by contractors, given their role in execution and competitiveness (Ozorhon *et al.*, 2010).

For technology capability, all three groups rated this factor highly, with clients and consultants assigning it a top mean rank of 3, while contractors ranked it slightly lower at 5. Despite contractors placing a somewhat lower ordinal rank on this driver, they gave it a higher mean score (4.48) compared to clients (4.22), indicating a stronger intensity of agreement. The low within-group variability suggests these differences in perception are substantively meaningful. This pattern implies that contractors view organisational capacity to acquire, develop, and apply technologies as especially critical, consistent with their role in project execution, where technical competence directly influences performance outcomes. Clients, conversely, while acknowledging its importance through high ranking, may consider technological capability less decisive relative to broader strategic or financial factors. This interpretation aligns with previous research identifying technological capability as a foundational element for competitive advantage in construction (Bossink, 2004; Ozorhon, 2013).

For technology fusion, the divergence is even more pronounced. Contractors rated this factor significantly higher (Mean = 4.28) than clients (Mean = 3.96) and consultants (Mean = 4.06). The mean ranks reveal contractors assigning technology fusion a mean rank of 9, clients a lower mean rank of 14, and consultants the lowest rank of 19. Unlike technology push and technology capability, technology fusion was not universally top-ranked; clients placed it near the bottom, indicating that they may underestimate its contribution to innovation. In contrast, contractors recognised its importance, ranking it 9th, reflecting their appreciation for integrating diverse digital tools, building systems, and construction technologies to achieve innovative outcomes. Prior studies underscore that technological integration is a central mechanism for realising innovation benefits in construction (Gambatese and Hallowell, 2011; Ozorhon, Abbott and Aouad, 2014).

Taken together, these findings suggest that different organisational groups prioritise innovation drivers according to their functional roles within the construction ecosystem. Contractors place the greatest emphasis on resource- and cost-related factors such as training, absorptive capacity, R&D, subsidies, and technology push. Consultants tend to occupy an intermediate position, valuing systemic integration through technological capability and technology fusion, while developers lean more toward financial and managerial considerations. These patterns indicate that policies to foster construction innovation in Malaysia must adopt a stakeholder-sensitive approach: training and subsidy schemes should be targeted towards contractors and SMEs, while regulatory and technological integration initiatives may be most effectively championed through consultants and government agencies.

4.8.3 Comparison With Other Studies

A comparison between the findings of the present study and those of previous research conducted in different countries was undertaken with the objective of consolidating and validating the results of this study. Table 4.6 summarises selected international studies from countries including Russia, Turkey, New Zealand, China, Nigeria, and Vietnam. To ensure the contemporaneity and relevance of the analysis, all studies considered were conducted within the last decade. Through this comparative examination, it is evident that the key drivers identified in the Malaysian construction industry correspond closely with those recognised in other national contexts. In particular, environment and sustainability, and strategic alliances were found to be among the most frequently cited drivers across multiple studies, underscoring their global significance as major catalysts for construction innovation.

Furthermore, subsidies and technology capability were also commonly observed in other contexts, appearing in four and three studies respectively. Their recurrence supports the notion that both external financial support and internal technological competence are integral components of innovation systems, particularly within developing economies. Conversely, technology push was less frequently reported, suggesting that while emerging technologies contribute to innovation, their influence is often mediated by contextual factors such as market readiness and institutional policies.

Overall, this comparative assessment serves as a form of triangulation, reinforcing the credibility of the present study's findings. The consistency between Malaysia's results and those from other developing countries demonstrates that innovation in the construction industry is driven by a combination of environmental, strategic, financial, and technological factors. Hence, the findings of this research can be viewed as a valid reflection of broader innovation trends within the global construction industry.

Table 4.6: Comparative Analysis of Drivers of Construction Innovation in this Study and Previous Studies.

	Top Five Drivers of Construction Innovation Identified in the Current Study				
	Technology Push	Environment and Sustainability	Technology Capability	Strategic Alliances	Subsidies
Malaysia (This study, 2025)	✓	✓	✓	✓	✓
Russia (Suprun and Stewart, 2015)			✓	✓	✓
Turkey (Ozorhon, Oral and Demirkesen, 2016)	✓	✓	✓		
New Zealand (Hunt and Gonzalez, 2018)				✓	✓
China (Gong and Wang, 2022)		✓		✓	✓
Nigeria (Ariono, Wasesa and Dhewanto, 2022)		✓		✓	
Vietnam (Van Nguyen, 2023)		✓			
Total	2	5	3	5	4

4.8.4 Factor Analysis

4.8.4.1 Kaiser-Meyer-Olkin (KMO) Test and Barlett's Test

Before conducting factor analysis, the adequacy of the dataset was assessed using the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's Test of Sphericity. As shown in Table 4.7, the KMO value was 0.863, which exceeds the minimum acceptable threshold of 0.6 (Kaiser, 1974) and indicates that the sample was suitable for factor analysis. In addition, Bartlett's Test of Sphericity yielded a chi-square value of 1316.734 with 231 degrees of freedom, which was statistically significant at $p < 0.001$. This result suggests that the correlation matrix is not an identity matrix, and therefore, the variables are sufficiently interrelated to justify the application of factor analysis (Bartlett, 1954; Hair *et al.*, 2019). Together, these tests confirm the appropriateness of the dataset for further factor extraction.

Table 4.7: Results of KMO and Barlett's Tests for Drivers of Construction Innovation.

Parameter	Value
Kaiser-Meyer-Olkin measure of sampling adequacy	0.863
Barlett's test of sphericity	
Approximate chi-square	1316.734
Degree of freedom	231
Significance	< 0.001

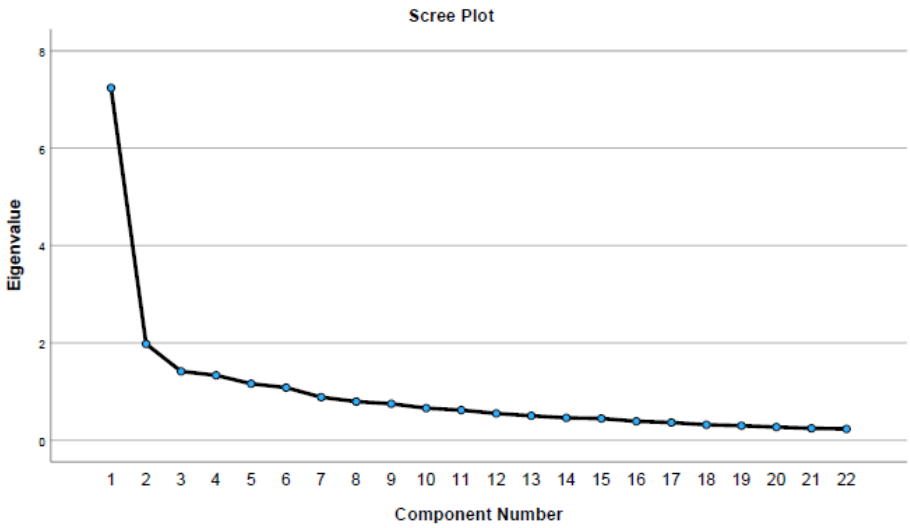

Figure 4.5: Scree Plot for 22 Drivers of Construction Innovation.

The scree plot presented in Figure 4.5 depicts the eigenvalues corresponding to each of the 22 components extracted in the exploratory factor analysis of the drivers of construction innovation. The steep decline in eigenvalues is observed from the first component, with values dropping sharply after the second component. Notably, an inflexion point, or "elbow," appears at the sixth component, where the curve transitions to a more gradual descent. This characteristic "elbow" in the scree plot indicates that the first six factors capture the majority of the systematic variance within the data, whereas subsequent components contribute relatively minimal additional explanatory power (Costello and Osborne, 2005). Accordingly, this graphical evidence justifies the retention of six factors in the analysis, supporting the factor solution that accounts for 64.60% of the total variance. Retention of these six factors aligns with established practice that balances explanatory completeness with parsimony, ensuring the factor model is both interpretable and statistically sound. In line with the recommendation by Hair et al. (2019), a minimum factor loading threshold of 0.40 was adopted for this study. Items with loadings below this cut-off were removed, as they did not demonstrate adequate correlation with their respective constructs. Specifically, the item “project performance improvement” was removed, as its loading fell below the acceptable level, indicating insufficient representation of its underlying construct. The removal strengthened the construct validity of the retained factors. Table 4.8 and Figure 4.6 illustrate the outcomes of the factor analysis, whereby the 22 identified drivers of construction innovation were systematically consolidated into six underlying factors, each representing a distinct thematic dimension of innovation drivers.

Table 4.8: Factor Loading and Variance Explained for Drivers of Construction Innovation.

Details of Underlying Factors	Factor Loading	Variance Explained (%)	Average Mean
Factor 1: Institutional and Technological Drivers		12.319	4.218
Subsidies	0.772		
Innovation stimulating regulations	0.711		
Technology fusion	0.697		
Technology capability	0.586		
Factor 2: Collaboration and Market Drivers		11.040	4.030
Programs promoting collaboration	0.750		
Market pull/client requirement	0.669		
Design trends	0.607		
Leadership	0.514		
Factor 3: Competition and Complexity		10.437	4.117
Competition level	0.693		
Project complexity	0.682		
Integrated design-build	0.558		
Factor 4: Sustainability and Capacity		10.378	4.267
Environment and sustainability	0.732		
Absorptive capacity	0.681		
Training	0.443		

Table 4.8 (Continued)

Factor 5: Leadership and Integration		10.285	4.073
Empowerment of innovation champions/leaders	0.726		
Corporate social responsibility	0.648		
Coordination of participating groups	0.608		
Integrated and informal R&D function	0.563		
Factor 6: Alliances and Knowledge		10.135	4.337
Strategic alliances	0.801		
Creation of knowledge networks	0.723		
Technology push	0.721		
Cumulative variance explained		64.595	

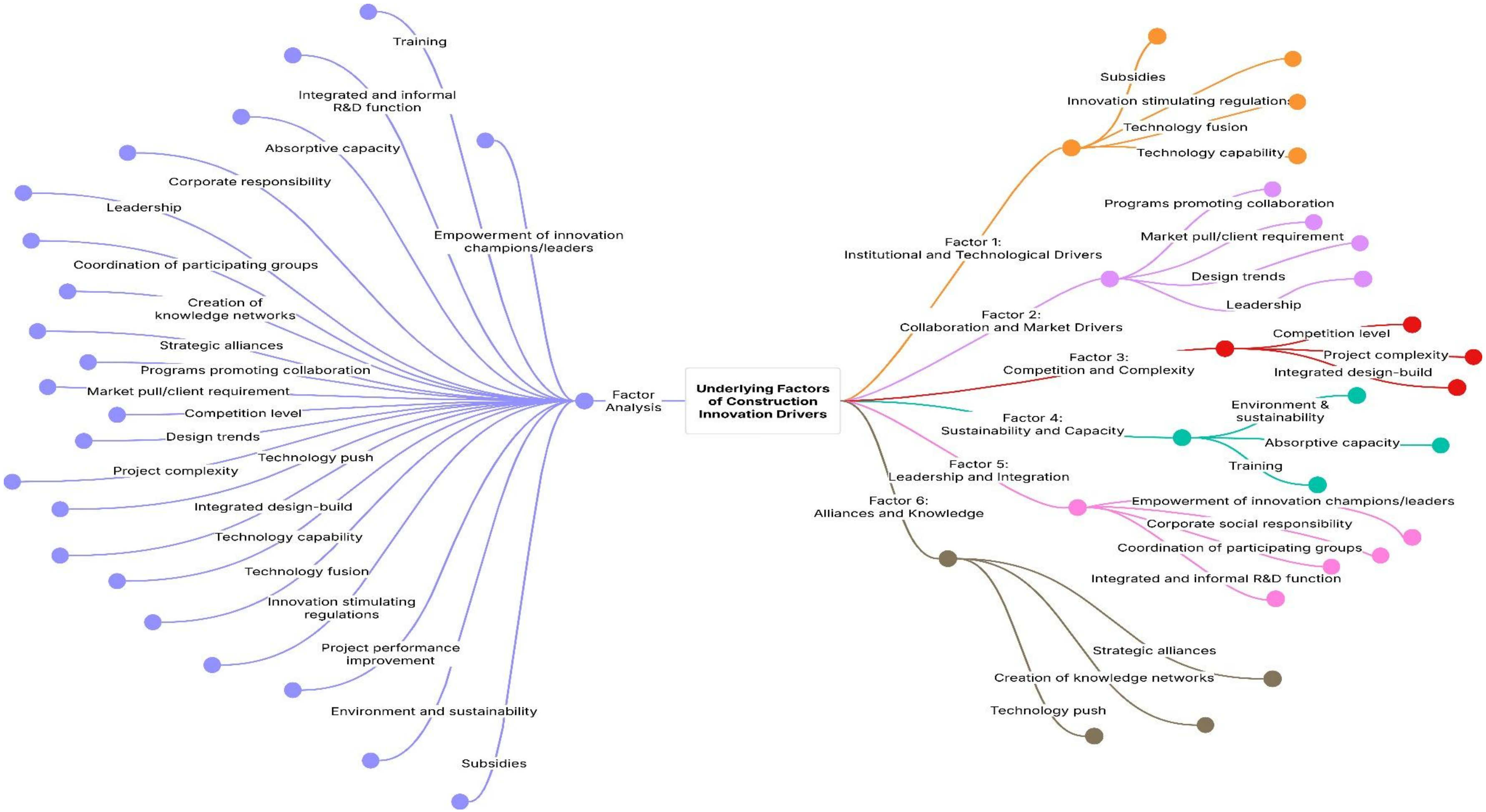

Figure 4.6: Factor Analysis Map for Drivers of Construction Innovation.

4.8.4.2 Extraction of Underlying Factor

Factor 1: Institutional and Technological Drivers

Institutional mechanisms and technological capabilities represent the most influential drivers of innovation in the construction industry, together explaining 12.32% of the variance in this study. Their combined impact underscores how financial incentives, regulatory frameworks, and technological readiness collectively shape the conditions under which firms experiment, adopt new practices, and restructure operations to align with ongoing industry transformation.

Government-led interventions play a critical role in reducing the risks and costs of innovation while creating incentives for firms to pursue experimentation. Subsidies, for instance, lower financial barriers to adopting advanced materials, digital technologies, and sustainable solutions. Earlier observations by Bossink (2004) noted how subsidies encouraged clients and architects to incorporate innovative practices into project requirements, while more recent findings highlight their continued relevance in accelerating industry transitions. Gong and Wang (2022) demonstrate that subsidies not only ease adoption costs but also improve firms' credibility with private investors, thereby amplifying the effectiveness of internal R&D investments. Similarly, Ozorhon and Oral (2017) emphasise that grants and government programmes stimulate industry-wide innovation ecosystems by strengthening collaboration between firms, universities, and policy agencies. Yet, subsidies are not without limitations. Wang, Lin and Li (2019) caution that their effectiveness is strongest in early development stages, as prolonged dependence may discourage firms from developing autonomous innovation capacity. This suggests that subsidy schemes must be strategically designed and flexible enough to encourage risk-taking but disciplined enough to prevent inefficiencies.

Complementing financial support, regulatory frameworks serve as another institutional lever that strongly shapes innovation trajectories. Performance-based regulations, which define outcomes rather than prescribing rigid processes, encourage firms to devise creative, context-specific solutions. Evidence from Malaysia and China demonstrates how performance-oriented regulatory reforms, when combined with partnerships with research institutions, accelerated the adoption of Building Information Modelling (BIM) and improved both project delivery and sustainability outcomes (Ariono, Wasesa and Dhewanto, 2022). Blayse and Manley (2004) already highlighted that flexible regulation stimulates innovation, while overly prescriptive frameworks risk reinforcing conventional practices. Practical cases, such as environmental legislation in the Netherlands, illustrate how ambitious standards compel firms to innovate to remain compliant (Bossink, 2004). More recently, Ozorhon, Oral and Demirkesen (2016) show that performance standards exert direct pressure on construction firms to adopt advanced practices, while other scholars stress that effective collaboration between regulators and industry actors is essential to overcome implementation challenges. These insights suggest that regulatory frameworks can act as powerful innovation catalysts, provided they strike the right balance between accountability and flexibility and are supported by regulatory bodies with sufficient technical expertise

In parallel, technological capability and fusion represent the internal capacity of firms to translate institutional support into actionable innovation. Technological capability refers to the ability to develop, adapt, and apply advanced tools and processes, often reinforced by continuous R&D and targeted technology programmes (Bossink, 2004). While early perspectives from Nam and Tatum (1992) stressed that technological progress often anticipates project demands, recent studies extend this argument by highlighting how digitalisation, BIM, and smart technologies now reshape not only project delivery but also client expectations and strategic decision-making (Ratana Singaram *et al.*, 2023). Technology fusion, defined as the integration of diverse technological domains, further accelerates innovation by enabling firms to tackle complex challenges holistically. For example, combining digital modelling with sustainable construction technologies generates synergies that enhance efficiency while reducing environmental impact. Such integration is no longer optional; rather, it is becoming a prerequisite for firms seeking to maintain competitiveness in an industry increasingly defined by complexity, sustainability, and globalised competition.

Taken together, this factor highlights that the alignment of subsidies, regulatory frameworks, and technological capability forms a systemic foundation for innovation. Financial incentives reduce risks, performance-based regulations create adaptive room for experimentation, and technological readiness ensures effective implementation. When these drivers are strategically integrated, they transform the construction industry from a reactive adopter of external change into a proactive innovator capable of sustaining long-term competitiveness, environmental responsibility, and global relevance.

Factor 2:Collaboration and Market Drivers

Collaboration and market dynamics emerge as central forces shaping innovation in the construction industry, together explaining 11.04% of the variance in this study. Unlike isolated initiatives, these drivers operate through interdependent mechanisms that combine institutional support, client demand, evolving design practices, and leadership influence, thereby positioning innovation as both a strategic necessity and a systemic process embedded across the industry.

Collaboration plays a pivotal role in addressing the fragmentation that often hinders knowledge transfer and innovation in construction. Programs that encourage multi-stakeholder involvement enable firms to pool expertise and overcome siloed practices. Ariono, Wasesa and Dhewanto (2022) show that government-led initiatives, such as those fostering BIM adoption, strengthen skill development and institutionalise knowledge transfer, leading to more resilient innovation ecosystems. Earlier work by Bossink (2004) similarly noted that collaboration between architects, contractors, and researchers translates academic knowledge into practical solutions, demonstrating that cooperation has long been a cornerstone of innovation. In practice, collaboration empowers smaller firms to access resources and technical capabilities otherwise beyond reach, embedding innovation into collective routines rather than leaving it as a series of isolated projects. This suggests that collaboration is not merely about communication, but about cultivating shared responsibility that sustains innovation over time.

While collaboration establishes the infrastructure for innovation, client and market pressures create the momentum that drives firms to act. Clients, particularly public agencies, exert influence by demanding higher standards of sustainability, digitalisation, and lifecycle performance. Evidence from emerging contexts, such as China and Croatia, demonstrates how client requirements accelerate BIM adoption and improve delivery outcomes (Ariono, Wasesa and Dhewanto, 2022). Blayse and Manley (2004) provide early recognition of this dynamic, showing that experienced and demanding clients compel firms to innovate, while more recent studies highlight that procurement strategies embedding sustainability criteria institutionalise advanced practices Van Nguyen (2023). Yet client influence is ambivalent: while progressive clients stimulate innovation, conservative preferences can reinforce traditional practices, slowing adoption. This tension highlights that the extent of client influence depends not just on demand, but on how firms interpret and operationalise these pressures.

Design trends function as a critical bridge between market forces and technical innovation. Innovative design translates abstract demands into tangible solutions that reshape construction processes. According to Ozorhon, Oral and Demirkesen (2016), design innovation stimulates advancements by stretching both technical and creative boundaries, while Owolabi et al. (2019) rank design among the leading drivers of industry innovation. Integrated and collaborative design practices further amplify this effect by aligning stakeholders and encouraging experimentation (Ozorhon and Oral, 2017). Importantly, design not only reflects external pressures but also generates internal capabilities, equipping firms with competencies that extend beyond immediate project needs. In this sense, design acts as both a response to market demand and a proactive driver of industry transformation.

Leadership weaves together collaboration, client demand, and design into a coherent strategic direction. Effective leaders mobilise resources, align stakeholders, and cultivate an environment that enables experimentation. Ariono, Wasesa and Dhewanto (2022) identify leadership as a decisive factor in BIM adoption, where innovation leaders design supportive policies and allocate resources to overcome institutional resistance. Ozorhon, Oral and Demirkesen (2016) argue that leadership shapes the “project spirit,” motivating teams and integrating diverse perspectives into collective outcomes. Institutional leadership, exemplified by agencies such as Malaysia's Construction Industry Development Board (CIDB), illustrates how policy and training initiatives can set the agenda for innovation at the industry level. Leadership, therefore, is not confined to executives but represents a dynamic capability that aligns organisational and industry capacities with evolving client and market demands.

Overall, the integration of collaborative structures, client and market pressures, design innovation, and leadership commitment demonstrates that innovation in construction emerges from the interaction of both internal coordination and external demand. Collaboration provides the platform for knowledge exchange, clients and markets generate urgency, design converts pressures into technical opportunities, and leadership ensures alignment and execution. Together, these forces operate as a mutually reinforcing system that positions collaboration and market drivers as foundational pillars of construction innovation.

Factor 3:Competition and Complexity

Competition and complexity emerge as the third factor generated through factor analysis, collectively explaining 10.44% of the variance in this study. These elements demonstrate that innovation is not only shaped by external institutions but also by market realities, project challenges, and the structural mechanisms that link design with delivery.

Competition exerts a powerful influence on innovation, compelling firms to adopt modern technologies and improve efficiency, quality, and overall competitiveness. Gambatese and Hallowell (2011) argue that innovation is often motivated by the need to achieve cost savings, productivity gains, and quality improvements, all of which strengthen a firm's market position. Similarly, Ozorhon, Oral and Demirkesen (2016) reinforce that innovation is indispensable for firms competing in globalised markets, where rising competition necessitates superior performance outcomes. Yet, competition is a double-edged sword: while it pressures firms to innovate, it may also push them toward short-term cost-cutting strategies that undermine sustainable innovation. Classic insights from Tatum (1989) highlight that successful innovations generate long-term competitive advantages by shaping business strategies and differentiating firms within saturated markets, but such benefits only materialise when firms balance short-term efficiency with long-term capability building. More recently, Ratana Singaram et al. (2023) demonstrate that technologies like BIM and IoT strengthen competitiveness by enhancing sustainability and project outcomes, while Ozorhon and Oral (2017) emphasise that advancements in communication tools, new materials, and digital solutions enable firms to sustain their competitive edge. In this sense, competition serves as both a catalyst and a test: firms that embrace technological adoption strategically thrive, while those that respond only reactively risk stagnation.

Project complexity further amplifies the need for innovation by presenting firms with unique technical and organisational challenges that cannot be addressed using conventional approaches. Nam and Tatum (1992) argue that technological advancements often precede problems, with innovation arising from extending or combining existing technologies to address increasingly complex project requirements. They emphasise that complex configurations, such as advanced structural systems, push firms toward informal R&D and long-term strategies to ensure effective delivery. This perspective challenges the traditional notion that innovation is merely reactive, positioning complexity as a proactive stimulus for experimentation and strategic development. Complementing this view, Ozorhon and Oral (2017) identify project complexity as a major driver of innovation, noting that bespoke designs and unpredictable project environments force firms to devise novel solutions tailored to unique client requirements. At the same time, complexity carries inherent risks: without adequate resources, smaller firms may struggle to manage uncertainty, which can turn complexity from an innovation driver into a project constraint. This suggests that innovation derived from complexity is not automatic, but contingent on a firm’s ability to mobilise knowledge, skills, and collaborative networks to turn challenges into opportunities.

The integration of design and build functions acts as a structural mechanism that facilitates innovation by breaking down silos and fostering collaboration. Bossink (2004) highlights that early collaboration between architects, contractors, and clients promotes interdisciplinary problem-solving, enabling the practical application of innovative concepts such as ecological design solutions. Building on this, Meng and Brown (2018) stress that design-build partnerships are particularly effective for larger firms, where integrated teams can overcome inefficiencies inherent in fragmented project structures. Similarly, Ozorhon and Oral (2017) emphasise the importance of early contractor involvement and cooperative project cultures, noting that these arrangements encourage experimentation, enhance constructability, and create opportunities for value-adding innovation. The effectiveness of such integration, however, depends on the quality of collaboration: if treated as a contractual arrangement rather than a genuine cultural shift, design-build may deliver efficiency gains but fail to unlock deeper innovation. When implemented effectively, integrated delivery provides a platform where knowledge-sharing, risk-taking, and collective problem-solving flourish, making it a transformative enabler rather than a procedural necessity.

Taken together, this factor demonstrates that competition, project complexity, and integrated design-build are mutually reinforcing drivers of construction innovation. Competition establishes the external pressures that compel firms to innovate; complexity creates project-level demands that necessitate novel solutions; and integrated delivery models provide the structural and cultural mechanisms to transform these pressures into actionable innovations. Yet their effectiveness is conditional: competition without long-term orientation risks shallow adaptation, complexity without adequate capacity risks inefficiency, and integration without cultural commitment risks proceduralism. When aligned, however, these forces highlight how construction innovation arises from the dynamic interplay between external pressures, technical challenges, and collaborative practices.

Factor 4: Sustainability and Capacity

Sustainability and capacity factors, which explained 10.38% of the total variance, capture how environmental sustainability and organisational capacity combine to drive innovation in the construction industry. They underscore that innovation is not only a response to external pressures but also a function of internal capabilities that enable firms to adapt, learn, and thrive in a rapidly evolving industry.

Sustainability pressures have become increasingly central to innovation pathways. Ariono, Wasesa and Dhewanto (2022) show how environmental challenges in developing economies drive the adoption of green building standards, smart city initiatives, and BIM-enabled systems for efficient material management. Similarly, Meng and Brown (2018) argue that sustainability has shifted from being an optional practice to a strategic priority, with sustainable design and construction now embedded in organisational agendas. These findings echo wider industry trends, where climate change, carbon reduction targets, and client expectations converge to push firms toward greener technologies and processes. Innovation is therefore no longer a discretionary activity but a necessary response to ecological and societal demands.

At the same time, absorptive capacity is essential in determining whether firms can convert sustainability goals into practical outcomes. Ariono et al. (2022) identify absorptive capacity as a key enabler of BIM innovation, particularly in contexts where firms must assimilate and apply external knowledge. Eadie et al. (2013) further highlight that organisations with higher absorptive capacity are better positioned to collaborate, integrate external expertise, and adapt new technologies effectively. Training plays a reinforcing role, with Chegu Badrinath, Chang and Hsieh (2016) emphasising the integration of BIM training in higher education to close knowledge gaps and prepare future professionals, while industry-led initiatives such as those noted by Ariono et al. (2022) provide targeted upskilling for current practitioners. This demonstrates that capacity is not a static attribute but one that requires continual investment through education, training, and organisational learning.

Taken together, sustainability and absorptive capacity represent mutually reinforcing dimensions: sustainability sets the agenda for innovation, while capacity determines whether firms can meet that agenda effectively. A growing concern, however, is the gap between ambition and implementation. Many firms adopt sustainability rhetoric but lack the internal capacity to translate it into measurable outcomes, risking superficial compliance rather than genuine transformation. The implication is clear: innovation cannot be sustained by external pressure alone but must be underpinned by robust organisational readiness.

Factor 5: Leadership and Integration

Factor 5, which accounts for 10.29% of the total variance, highlights the centrality of leadership and integration in driving innovation within the construction industry. These drivers function through mechanisms of vision-setting, empowerment, coordination, and knowledge sharing, ensuring that innovation does not remain fragmented or incidental but instead becomes institutionalised across organisations and projects. Leadership creates the momentum and legitimacy for change, while integration translates this direction into coordinated actions that link people, processes, and technologies. Together, they form the organisational backbone of innovation.

The empowerment of innovation champions and leaders plays a pivotal role in mobilising change. While early contributions (Tatum, 1986, 1989; Blayse & Manley, 2004) established the importance of champions as agents capable of overcoming resistance and uncertainty, recent studies emphasise the need to cultivate distributed leadership within firms. Ariono, Wasesa and Dhewanto (2022) illustrate how innovation leaders, particularly in the context of BIM adoption in developing countries, provide the resources, vision, and institutional support necessary to overcome systemic barriers. Similarly, Ozorhon, Oral and Demirkesen (2016) highlight that leadership commitment directly influences corporate innovation culture by setting expectations and allocating resources for experimentation. In practice, empowering champions ensures that innovative initiatives are not isolated but connected to broader organisational strategies, increasing their likelihood of diffusion and long-term success. Leadership in this sense is less about hierarchical authority and more about creating enabling conditions for collective innovation.

Integration mechanisms further reinforce innovation by linking diverse groups, processes, and knowledge domains. Coordination across stakeholders is essential to overcome the fragmentation traditionally associated with the construction sector. Ariono, Wasesa and Dhewanto (2022) highlight how tools such as BIM platforms (e.g., Revit, Navisworks) streamline multidisciplinary collaboration by improving clash detection and design integration. Similarly, Huggins and Thompson (2017) stress that relational governance, formal partnerships, and strategic alliances create structured channels for knowledge exchange, moving beyond reliance on informal networks. Hunt and Gonzalez (2018) add that diverse professional networks and strong contractor–consultant relationships foster inter-organisational learning and accelerate innovation diffusion. These findings suggest that effective integration is not simply about operational efficiency but also about creating collaborative environments where new ideas can be generated, tested, and scaled.

A further dimension of integration lies in the role of R&D within construction firms. Although historically emphasised as an informal and incremental process (Nam & Tatum, 1992; Bossink, 2004), more recent perspectives recognise that embedding integrated R&D into everyday practice is indispensable for sustaining innovation. Ariono, Wasesa and Dhewanto (2022) show that integrated R&D functions underpin BIM adoption by linking research efforts with practical design and construction challenges. Similarly, Becerik-Gerber, Gerber and Ku (2011) argue for closer integration between research, education, and industry practice to address the complex and multidisciplinary problems characteristic of the AEC sector. When R&D is institutionalised as part of normal operations rather than an isolated activity, firms are better able to anticipate technological shifts, shape client expectations, and sustain long-term competitiveness.

Corporate social responsibility (CSR) also intersects with leadership and integration by aligning innovation efforts with broader societal and environmental objectives. Ozorhon, Oral and Demirkesen (2016) highlight that CSR enhances corporate image and client trust, indirectly fostering innovation by creating incentives for firms to adopt sustainable and socially responsible practices. More recently, Ozorhon and Oral (2017) emphasise that CSR is no longer a peripheral activity but a strategic driver of green innovation, as firms integrate environmental goals into core operations. This alignment ensures that innovation is not only internally driven by champions and coordination mechanisms but also externally validated through stakeholder expectations and societal pressures.

Overall, Factor 5 demonstrates that leadership and integration operate in mutually reinforcing ways to drive innovation in the construction industry. Leadership provides vision, empowers champions, and legitimises experimentation, while integration ensures that diverse actors, processes, and technologies are aligned to achieve shared outcomes. Together, they transform innovation from a series of ad hoc initiatives into a systemic, embedded practice. In an increasingly complex and competitive industry, firms that cultivate distributed leadership and institutionalised integration are likely to be better positioned to sustain innovation, enhance competitiveness, and deliver long-term value.

Factor 6: Alliances and Knowledge

Factor 6, which explains 10.14% of the total variance, emphasises the pivotal role of strategic alliances and knowledge networks in driving innovation in the construction industry. Strategic alliances, as highlighted by Ariono, Wasesa and Dhewanto (2022), are particularly important in developing countries, where long-term partnerships with clients, contractors, and IT specialists enable the adoption of BIM and other advanced practices. Such alliances provide a structured platform for process integration, reduce fragmentation, and allow firms to pool resources toward innovative outcomes. Historical cases, such as the collaboration between Shimizu Corporation and Mitsubishi Heavy Industries, illustrate how alliances have supported the development of advanced construction technologies (Kangari & Miyatake, 1997), while Bossink (2004) stresses their importance in sharing risks and leveraging capabilities, especially in sustainable construction. These examples suggest that alliances are not merely contractual arrangements but mechanisms for building trust, sharing knowledge, and mobilising collective resources to overcome technical and financial uncertainties.

Parallel to alliances, the creation of knowledge networks provides a complementary mechanism for fostering innovation. Knowledge networks function by connecting universities, research institutions, businesses, and government agencies, enabling the exchange of expertise and the transfer of tacit and explicit knowledge. As noted by Blayse and Manley (2004), universities and research bodies often act as “innovation brokers,” orchestrating cooperation and disseminating knowledge across the sector. Government initiatives, such as knowledge centres for sustainable construction, further amplify this process (Bossink, 2004), while digital platforms and ICT tools enhance communication between project teams and institutional partners, making knowledge transfer more efficient (Oladapo, 2007). Moreover, embedding knowledge gained from projects into ongoing business activities, as recommended by Wei and Lam (2014), ensures that learning is not lost but continually informs new practices. This capacity to link different knowledge bases—regional, institutional, and organisational—creates a foundation for localised yet scalable innovation (Wang, Lin & Li, 2019).

It becomes increasingly clear that alliances and knowledge networks reinforce one another: alliances provide the organisational and relational structure for collaboration, while networks supply the channels through which information and expertise circulate. Together, they reduce duplication of efforts, enable firms to tackle complex problems collectively, and create an environment where experimentation and learning are sustained. This interplay is especially crucial in the construction industry, where fragmented structures often inhibit innovation. By embedding both long-term alliances and robust knowledge networks into industry practices, firms are better positioned to cultivate resilience, enhance sustainability, and achieve continuous innovation across projects and regions.

4.9 Barriers of Construction Innovation in Malaysia

4.9.1 Mean Score and Standard Deviation

The barriers of construction innovation in Malaysia are ranked in accordance with the mean and standard deviation computed as shown in Table 4.9. Overall, the five most critical drivers of construction innovation are:

(i) Lack of financial resource (Mean = 4.39, SD = 0.623).

(ii) Operational resource gap (Mean = 4.32, SD = 0.606).

(iii) Lack of technical capabilities (Mean = 4.29, SD = 0.669).

(iv) Lack of incentives (Mean = 4.21, SD = 0.710).

(v) Inappropriate legislation (Mean = 4.18, SD = 0.705).

Lack of financial resources is the most critical barrier to innovation in the construction industry. High software acquisition and implementation costs, coupled with the continued reliance on traditional methods, significantly discourage the adoption of new technologies (Ariono, Wasesa & Dhewanto, 2022). Firms with high debt ratios or low operational efficiency face further limitations in allocating funds for R&D, thereby restricting opportunities for innovation (Gong & Wang, 2022). This challenge is especially acute among SMEs, which often lack the capital to invest in advanced tools and equipment necessary for innovation (Ratana Singaram et al., 2023). Limited funding not only hampers the adoption of cutting-edge technologies but also compels firms to rely on conventional practices, reinforcing the industry's low innovation capacity (Ozorhon, Oral & Demirkesen, 2016). In the Malaysian context, this finding is particularly relevant given that SMEs dominate the construction sector (Lada *et al.*, 2023). The inability of these firms to finance innovation suggests that external support mechanisms, such as targeted subsidies or soft loans, may be critical to overcoming this barrier.

Operational resource gaps also emerge as a major barrier, reflecting disparities in financial, material, and organisational capacity. Larger firms are generally better positioned to invest in R&D and absorb the risks associated with innovation, whereas smaller firms face constraints that reduce their ability to explore new solutions (Meng & Brown, 2018). Access to innovation inputs such as capital and materials is also uneven, with state-owned firms often better resourced than private contractors (Gong & Wang, 2022). In addition, shortages of advanced construction materials hinder the adoption of new methods and slow down project progress (Ozorhon et al., 2016). These findings underline how operational limitations restrict experimentation and reduce the overall pace of innovation. For Malaysia, this suggests that bridging the resource gap between large and small firms is vital. Industry collaboration and resource-sharing platforms, such as joint R&D projects or pooled procurement systems, could help alleviate these disparities.

The lack of technical capabilities is another significant obstacle to innovation. Advanced technologies such as BIM demand skilled personnel who can manage workflows, training, and collaboration, yet many firms lack the necessary expertise (Arayici et al., 2009). Deficiencies in technical knowledge, including limited understanding of sustainable construction practices and knowledge transfer, further hinder firms' ability to implement new systems effectively (Shabanesfahani, 2012). Regional challenges exacerbate the issue: for example, the absence of domestic BIM standards in China has restricted the use of BIM in prefabricated projects (Tan et al., 2019), while MEP firms in Nigeria have reported insufficient technical expertise as their greatest barrier to BIM adoption (Wang, Adetola & Abdul-Rahman, 2015). These findings demonstrate that without adequate technical capability, construction stakeholders struggle to harness the full potential of innovation. In Malaysia, where the construction workforce is heavily reliant on foreign labour, the lack of technical expertise may be even more pronounced (Mohd Nor, Subramaniam and Sahudin, 2023; Zainal *et al.*, 2023). This highlights the urgent need for continuous professional development and skill-building initiatives to ensure that workers are equipped to handle digital and sustainable innovations.

Lack of incentives is also widely recognised as a barrier to construction innovation. High upfront costs and perceived risks deter firms from investing in new technologies when adequate financial or policy-driven incentives are absent (Ariono et al., 2022). Moreover, existing incentive structures often prioritise cost-saving measures over broader design and process innovations, limiting opportunities for transformative advancements (Rose, Manley & Widen, 2019). This imbalance reduces motivation among consultants and contractors to pursue ambitious solutions, highlighting the need for improved incentive mechanisms that reward innovative practices. From the Malaysian perspective, this finding suggests that government-driven incentives must be carefully designed to go beyond cost efficiency and encourage the adoption of more comprehensive, sustainability-oriented innovations.

Finally, inappropriate legislation remains a persistent barrier to construction innovation. Outdated or fragmented legal frameworks hinder collaboration and knowledge sharing, creating uncertainties that discourage the adoption of digital tools such as BIM (Arayici et al., 2009; Olatunji, 2011). In Malaysia, the lack of mandatory government policies requiring BIM adoption in private projects has slowed its wider uptake (Ariono et al., 2022).

Legal ambiguities over model ownership, contractual responsibilities, and liability further exacerbate the issue, while overly rigid regulations often reinforce conventional practices instead of encouraging progressive solutions (Wei & Lam, 2014). These challenges underline the urgent need for legal reforms, including BIM-specific standards, clearer contractual provisions, and stronger policy mandates to support innovation. Based on the findings of this study, addressing legislative shortcomings could act as a catalyst for innovation by providing clarity and reducing the risks associated with adopting new technologies.

Table 4.9: Mean Score and Standard Deviation of Barriers of Construction Innovation in Malaysia.

Ref	Barriers of Construction Innovation	Overall (N=150)			Client/Developer (N=50)			Consultant (N=50)			Contractor (N=50)			Chi-square	Asymp. sig
		Mean	SD	R	Mean	SD	R	Mean	SD	R	Mean	SD	R		
Organisational Challenges															
B1	Unsupportive organisational culture	4.11	0.647	10	4.06	0.586	7	4.10	0.707	8	4.16	0.650	11	0.667	0.716
B2	Fear of change	3.95	0.638	20	3.98	0.622	16	3.98	0.654	15	3.90	0.647	20	0.529	0.767
B3	Lack of incentives	4.21	0.710	4	4.04	0.699	10	4.16	0.738	5	4.44	0.644	4	8.465	0.015*
B4	Organisational rigidity	3.97	0.639	18	3.92	0.566	18	3.84	0.738	20	4.14	0.572	12	5.740	0.057
B5	Lack of recognition from clients	3.96	0.750	19	3.88	0.746	20	3.88	0.689	19	4.12	0.799	14	4.834	0.089
Financial and Resource Limitations															
B6	Lack of financial resource	4.39	0.623	1	4.26	0.565	2	4.36	0.693	1	4.56	0.577	1	7.093	0.029*
B7	Operational resource gap	4.32	0.606	2	4.20	0.571	3	4.20	0.606	3	4.56	0.577	1	12.735	0.002**
B8	Preference for quick pay-off opportunities	3.99	0.660	16	4.00	0.700	13	3.96	0.638	17	4.02	0.654	18	0.213	0.899

Table 4.9 (Continued)

Technical and Knowledge Gaps															
B9	Limited innovation knowledge	4.14	0.645	7	4.26	0.633	1	4.02	0.553	12	4.14	0.729	13	4.401	0.111
B10	Lack of experienced and qualified staff	4.06	0.697	13	3.88	0.594	19	4.00	0.670	14	4.30	0.763	7	13.046	0.001**
B11	Lack of technical capabilities	4.29	0.669	3	4.14	0.572	6	4.28	0.607	2	4.44	0.787	3	8.688	0.013*
Project-Specific and Structural Constraints															
B12	Project-based production	3.97	0.695	17	3.92	0.665	17	4.04	0.669	11	3.96	0.755	19	0.773	0.679
B13	Temporary nature of projects	4.03	0.623	15	4.02	0.685	12	3.98	0.553	16	4.08	0.634	16	0.936	0.626
B14	Time constraints	4.12	0.694	9	3.98	0.714	15	4.18	0.596	4	4.20	0.756	9	3.330	0.189
B15	Complexity/scale of projects	4.12	0.713	8	4.02	0.622	11	4.17	0.700	6	4.20	0.808	10	2.354	0.308

Table 4.9 (Continued)

External and Systemic Barriers														
B16	Risk of failure	4.08	0.710	12	4.06	0.712	8	4.12	0.659	7	4.06	0.767	17	0.126	0.939
B17	Inappropriate legislation	4.18	0.705	5	4.16	0.681	4	3.94	0.712	18	4.44	0.644	4	12.705	0.002**
B18	Industry fragmentation	4.09	0.659	11	4.04	0.533	9	4.02	0.742	13	4.22	0.679	8	3.364	0.186
B19	Procurement systems (e.g., lump-sum contracts)	4.05	0.789	14	3.98	0.685	14	4.06	0.843	10	4.10	0.839	15	1.628	0.443
B20	Economic/political conditions	4.18	0.696	6	4.14	0.606	5	4.06	0.712	9	4.34	0.745	6	6.111	0.047*

N = Sample size, SD = Standard Deviation

Note:
**. The mean difference is statistiscally significant at the 0.01 level ($p < 0.01$).
*. The mean difference is statistically significant at the 0.05 level ($p < 0.05$).

4.9.2 Kruskal-Wallis H Test

As presented in Table 4.9, the Kruskal–Wallis test revealed that out of 20 identified barriers, seven factors demonstrated statistically significant differences in perception among clients/developers, consultants, and contractors at the 95% confidence level. These barriers are: lack of incentives ($p = 0.015$), lack of financial resources ($p = 0.029$), operational resource gap ($p = 0.002$), lack of experienced and qualified staff ($p = 0.001$), lack of technical capabilities ($p = 0.013$), inappropriate legislation ($p = 0.002$), and economic/political conditions ($p = 0.047$).

A closer examination of the mean rankings highlights several important trends. Contractors consistently reported higher concern over financial and resource-based barriers such as lack of financial resources (Mean = 4.56, Mean Rank = 1), operational resource gaps (Mean = 4.56, Mean Rank = 1), and lack of incentives (Mean = 4.44, Mean Rank = 4). This is expected, given that contractors are often directly exposed to the cash flow pressures and operational demands of project delivery. Previous studies confirm that financial constraints and resource shortages represent major deterrents to innovation adoption, particularly for firms operating at the execution stage of projects (Manley, 2008; Hwang and Ng, 2013). By contrast, developers and consultants, who operate more strategically and with relatively greater access to capital, tended to assign slightly lower rankings to these barriers.

For technical and knowledge-related constraints, contractors again expressed stronger concerns regarding the lack of qualified staff (Mean = 4.30, Mean Rank = 7) and technical capabilities (Mean = 4.44, Mean Rank = 3) compared to developers and consultants. This reinforces the argument by Blayse and Manley (2004) that human resource limitations are a primary barrier to construction innovation, as the implementation of new methods and technologies requires a skilled workforce with adequate technical knowledge. The discrepancy in mean ranks, where clients ranked lack of experienced staff as 19, also reflects the frontline role of contractors in managing site-level complexities, where the absence of expertise poses a more immediate challenge.

Interestingly, significant divergence was also observed in perceptions of inappropriate legislation. Contractors ranked it much higher (Mean = 4.44, Mean Rank = 4) compared with consultants (Mean = 3.94, Mean Rank = 18) and developers (Mean = 4.16, Mean Rank =4). This suggests that contractors view regulatory environments as particularly restrictive, especially where rigid compliance requirements may delay project timelines or increase costs. This aligns with the findings of Nam and Tatum (1992) and Zhang et al. (2023), who argue that fragmented and outdated regulatory systems often hinder innovation diffusion in the construction sector. Developers, by contrast, may perceive legislation as less obstructive given their greater influence during the planning and procurement stages.

Similarly, the test confirmed a statistically significant difference among stakeholder groups for economic and political conditions, with contractors assigning the highest concern (Mean = 4.34, Mean Rank = 6), followed by developers (Mean = 4.14, Mean Rank = 5) and consultants (Mean = 4.06, Mean Rank = 9). This finding indicates that contractors perceive systemic economic and political uncertainties, such as market volatility, policy changes, and economic fluctuations, as particularly constraining to innovation adoption. Although contractors have a slightly lower mean rank (6) than developers (5), their greater concern is reflected in higher mean scores, which represent absolute ratings of barrier severity. Comparable challenges have been reported in other developing countries, where economic and political instability limit firms' capacity to invest in novel technologies and practices (Bhavsar, Sridharan and Sudarsan, 2023; Al-Otaibi *et al.*, 2025). Addressing these barriers may therefore require targeted policy interventions to stabilise the construction environment and support innovation at the execution level.

The existence of these statistically significant differences underscores the stakeholder-specific nature of innovation barriers in Malaysia's construction industry. Contractors are disproportionately affected by operational, financial, and technical limitations, whereas consultants and developers perceive such barriers less critically. Policymakers and industry leaders should therefore design differentiated intervention strategies. For instance, targeted subsidies, training programs, and workforce development initiatives could address contractor-level constraints, while regulatory reforms might reduce the systemic barriers highlighted in the responses.

Overall, the Kruskal–Wallis results presented in Table 4.6 confirm that although all stakeholder groups acknowledge the presence of barriers to innovation, their severity is experienced differently across organisational roles. This reinforces the need for a multi-level approach that accounts for the distinct positions of developers, consultants, and contractors within the innovation ecosystem.

4.9.3 Comparison With Other Countries

A comparison between the findings of the present study and those of previous research conducted in different countries was undertaken to consolidate and validate the results of this study. Table 4.10 summarises selected international studies from countries including Russia, Nigeria, China, and Vietnam. To ensure the relevance and contemporaneity of the analysis, only studies conducted within the last decade were included. The comparative analysis reveals that the barriers identified in the Malaysian construction industry closely correspond with those recognised in other developing contexts. In particular, lack of technical capabilities and inappropriate legislation were the most frequently reported barriers, each identified in six studies, signifying their persistent and widespread influence on hindering construction innovation globally.

In addition, lack of financial resources and lack of incentives were also observed in several studies, highlighting the continuing challenge of insufficient financial support and limited motivation for innovation adoption in developing economies. Operational resource gap, though less frequently cited, remains a notable internal constraint that restricts firms' ability to allocate skilled personnel and manage innovation processes effectively. The recurrence of these barriers across different national contexts reinforces the credibility of the present findings, indicating that the Malaysian construction industry faces challenges similar to those encountered elsewhere in the developing world.

Overall, the comparative results provide strong triangulation for this study by confirming that the identified barriers are not context-specific but are consistent with international trends. The alignment of findings demonstrates that innovation in Malaysia's construction sector is constrained by both structural and institutional limitations, particularly related to technical capacity and regulatory frameworks. Thus, the outcomes of this study can be regarded as a valid reflection of the broader impediments to construction innovation prevalent across developing economies.

Table 4.10: Comparative Analysis of Barriers of Construction Innovation in this Study and Previous Studies.

	Top Five Barriers of Construction Innovation Identified in the Current Study				
	Lack of Financial Resource	Operational Resource Gap	Lack of Technical Capabilities	Lack of Incentives	Inappropriate Legislation
Malaysia (This study, 2025)	✓	✓	✓	✓	✓
Russia (Suprun and Stewart, 2015)			✓	✓	✓
China (Tan *et al.*, 2019)			✓		✓
Nigeria (Owolabi *et al.*, 2019)			✓		✓
Nigeria (Ariono, Wasesa and Dhewanto, 2022)	✓		✓		✓
Vietnam (Nguyen, 2023)	✓	✓	✓		✓
Total	3	2	6	2	6

4.9.4 Factor Analysis

4.9.4.1 Kaiser-Meyer-Olkin (KMO) Test and Barlett's Test

The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy for the barriers of construction innovation was 0.826 as shown in Table 4.11, indicating meritorious sampling adequacy (Kaiser, 1974). Bartlett's test of sphericity yielded a chi-square value of 1142.878 with 190 degrees of freedom, and a significance level of $p < 0.001$, confirming that the correlation matrix was suitable for factor analysis (Bartlett, 1954; Hair *et al.*, 2019). The scree plot for the 20 identified barriers illustrated in Figure 4.7 further supports the extraction of factors, as a clear inflexion point is observed after the fifth component, suggesting that five underlying factors adequately represent the data structure. Based on this graphical evidence, the retention of five factors was justified, accounting for 61.30% of the total variance. In accordance with the commonly recommended threshold of 0.40 for factor loadings, all items in this dataset exceeded the cut-off, indicating satisfactory representation of their respective constructs. As no items fell below the threshold, all were retained for further analysis, thereby supporting the robustness and construct validity of the measurement model. Table 4.12 and Figure 4.8 illustrate the outcomes of the factor analysis, whereby the 20 identified barriers of construction innovation were systematically consolidated into five underlying factors.

Table 4.11: Results of KMO and Barlett's Tests for Barriers of Construction Innovation.

Parameter	Value
Kaiser-Meyer-Olkin measure of sampling adequacy	0.826
Barlett's test of sphericity	
Approximate chi-square	1142.878
Degree of freedom	190
Significance	< 0.001

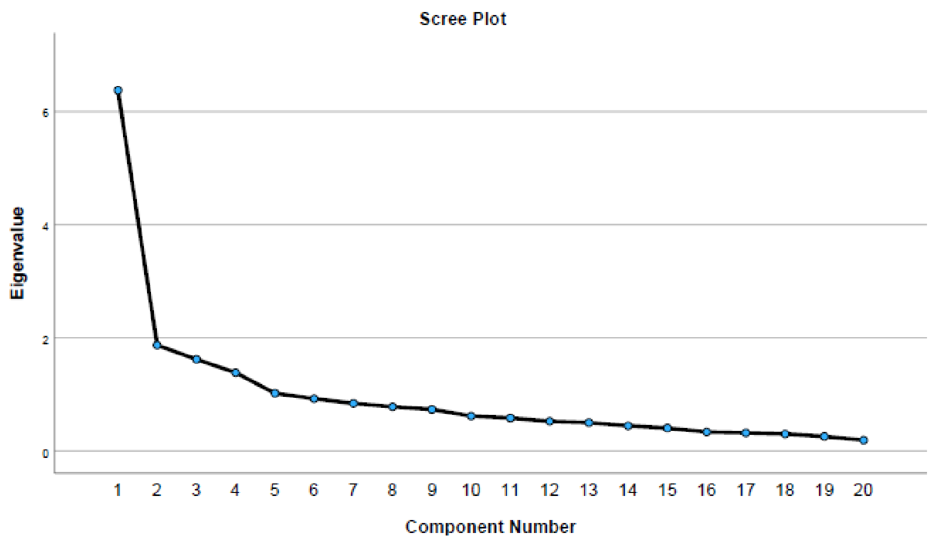

Figure 4.7: Scree Plot for 20 Barriers of Construction Innovation.

Table 4.12: Factor Loading and Variance Explained for Barriers of Construction Innovation.

Details of Underlying Factors	Factor Loading	Variance Explained (%)	Average Mean
Factor 1: Organisational Barriers		15.041	4.197
Lack of financial resource	0.791		
Operational resource gap	0.690		
Lack of incentives	0.667		
Organisational rigidity	0.527		
Inappropriate legislation	0.495		
Unsupportive organisational culture	0.479		
Factor 2: Capability Barriers		13.704	4.126
Lack of experienced and qualified staff	0.785		
Lack of technical capabilities	0.688		
Limited innovation knowledge	0.656		
Lack of recognition from clients	0.578		
Economic/politic conditions	0.542		
Factor 3: Structural Barriers		13.665	4.057
Industry fragmentation	0.751		
Procurement systems	0.728		
Temporary nature of projects	0.714		

Table 4.12 (Continued)

Factor 4: Behavioural Barriers		9.786	3.970
Fear of change	0.761		
Project-based production	0.574		
Preference for quick pay-off opportunities	0.401		
Factor 5: Temporal-Risk Barriers		9.109	4.107
Time constraints	0.725		
Complexity/scale of projects	0.607		
Risk of failure	0.476		
Cumulative variance explained		61.304	

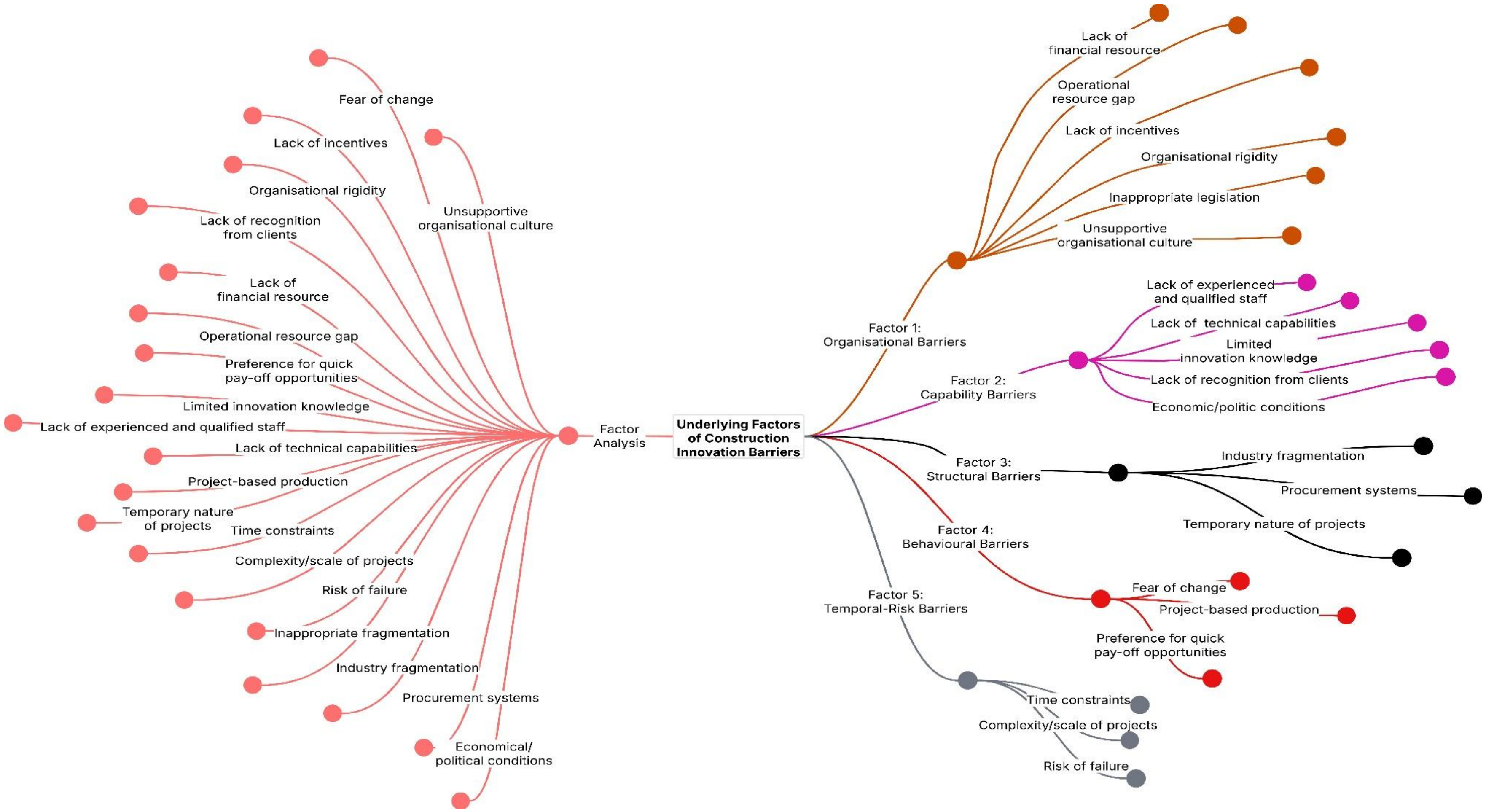

Figure 4.8: Factor Analysis Map for Barriers of Construction Innovation.

4.9.4.2 Extraction of Underlying Factor

Factor 1: Organisational Barriers

Organisational barriers emerge as the most influential constraint to construction innovation, explaining 15.04% of the total variance in this study. Unlike external constraints such as financial limitations or legislation, organisational barriers are embedded within firm-level structures, cultures, and routines, making them especially difficult to overcome. Their persistence is particularly damaging because they not only restrict immediate innovation adoption but also erode the long-term adaptive capacity of firms. This indicates that without targeted organisational reform, other enablers of innovation, such as incentives or external partnerships, will struggle to deliver meaningful outcomes.

A lack of supportive organisational culture consistently appears as one of the most fundamental obstacles. Resistance to change, entrenched traditional practices, and risk-averse mindsets discourage experimentation and limit firms' ability to respond to new opportunities (Arayici et al., 2009; Ozorhon, Oral & Demirkesen, 2016). Evidence from both developed and developing contexts shows that cultural inertia often translates into reluctance to adopt digital tools such as BIM or to invest in staff training, thereby reinforcing outdated practices (Ariono, Wasesa & Dhewanto, 2022). These patterns suggest that culture is not a passive background condition but an active barrier that systematically shapes decision-making and narrows the range of options leaders consider viable. What is particularly striking is how deeply cultural resistance interacts with other barriers: for example, firms with rigid cultures are less likely to create incentive systems, allocate resources to R&D, or pursue collaborative partnerships. This interdependence makes culture one of the most critical starting points for reform.

Closely tied to culture is organisational rigidity, which manifests through hierarchical structures, bureaucratic procedures, and inflexible workflows. Such rigidity hampers both intra- and inter-firm collaboration, limiting the exchange of knowledge and stifling creative problem-solving (Gambatese & Hallowell, 2011; Shabanesfahani, 2012). In construction, where projects often require bespoke solutions, this rigidity is particularly detrimental. A rigid firm may succeed in delivering standardised projects but will struggle when confronted with unique design requirements or sustainability targets that demand novel approaches. This highlights a paradox that the very stability that rigidity provides in routine operations becomes a liability when dynamic adaptation is required. Addressing this barrier therefore requires balancing stability with flexibility, ensuring processes are structured enough for efficiency but adaptable enough to accommodate innovation.

Another dimension of organisational barriers is the lack of incentives for innovation. Studies consistently show that firms reluctant to allocate resources to new technologies or methods often do so because internal reward systems favour short-term cost control over long-term value creation (Rose, Manley and Widen, 2019). This misalignment between project priorities and innovation goals discourages managers from championing new approaches, even when they recognise potential benefits. The evidence implies that incentive structures act as a silent but powerful determinant of behaviour, shaping whether individuals are willing to invest effort in experimentation. When innovation lacks clear rewards or recognition, it is unsurprising that managers default to safer, established methods. This suggests that reforming incentive structures is not a peripheral concern but a central requirement for embedding innovation into organisational practice.

Taken together, these findings show that organisational barriers form a self-reinforcing system: unsupportive cultures fuel rigidity, rigidity limits experimentation, and the absence of incentives discourages innovation efforts. What makes these barriers especially significant is not only their prevalence but also their interconnectedness, which creates a cycle of stagnation difficult to break. This underscores the need for a holistic response that addresses culture, structure, and incentives simultaneously rather than piecemeal. Without such integrated reform, firms risk remaining locked in outdated practices that undermine both competitiveness and long-term resilience in an increasingly complex and innovation-driven construction landscape.

Factor 2: Capability Barriers

Capability barriers emerge as the second factor generated through factor analysis, collectively explaining 13.70% of the variance in this study. Unlike organisational barriers, which stem largely from internal culture and structure, capability barriers reflect the sector's limited ability to build, sustain, and deploy the technical and human resources required for innovation. These barriers are particularly critical because they strike at the very foundation of innovation capacity: knowledge, skills, and expertise. Without strong capabilities, even the most supportive organisational environments or favourable market conditions cannot translate into successful adoption of new technologies or processes.

A recurring issue is the lack of experienced and qualified staff, which multiple studies identify as a decisive obstacle to innovation (Ariono, Wasesa & Dhewanto, 2022; Ozorhon, Oral & Demirkesen, 2016). The absence of skilled personnel not only limits firms' ability to implement advanced tools such as BIM but also undermines strategic leadership roles such as innovation managers, who are essential for championing new practices. Rose, Manley and Widen (2019) show how this shortage constrains sectors like road construction, where insufficient expertise prevents proper evaluation of new products. The evidence indicates that capability barriers are not simply a matter of having "too few" skilled workers; rather, they reveal systemic weaknesses in how the industry educates, trains, and retains talent. This highlights a deeper problem: reliance on external consultants or ad hoc training may address short-term needs but does little to build enduring internal expertise, leaving firms vulnerable to knowledge gaps whenever technologies evolve.

Closely linked is the lack of technical capabilities, which refers to deficits in applying, adapting, and integrating advanced technologies into project workflows. For instance, Arayici et al. (2009) highlight the significant challenges in transitioning to BIM, noting that firms often lack the technical infrastructure and skills to manage new processes effectively. Similarly, Shabanesfahani (2012) identifies weaknesses in areas such as green construction and knowledge transfer, which limit the adaptability of firms to innovation. These findings suggest that capability barriers extend beyond individual competence to organisational systems of learning. Where firms treat training as a one-off activity rather than an embedded process, technical capabilities remain fragmented and fragile. In practice, this means that even when firms adopt new technologies, they often fail to maximise their potential because workflows, standards, and knowledge-sharing mechanisms are underdeveloped.

Another dimension is the limited knowledge of innovation itself, which restricts stakeholders from recognising, assessing, or driving forward new solutions. Ariono, Wasesa and Dhewanto (2022) emphasise that in countries like Nigeria, limited understanding of BIM benefits and procedures slows adoption. This barrier is compounded when clients, who play a central role in stimulating innovation, lack the expertise to demand or evaluate advanced solutions (Lenderink et al., 2020). Tan et al. (2019) also underline how misunderstandings of BIM concepts create significant risks during implementation, leading to wasted resources and stakeholder frustration. Such knowledge gaps, whether among clients, consultants, or contractors, reveal that capability barriers are not confined to technical specialists; rather, they cut across the whole project ecosystem. This suggests that innovation requires a collective capacity to understand and operationalise new methods, not just isolated expertise.

Taken together, these barriers form a pattern where insufficient skills, weak technical capacity, and limited innovation knowledge reinforce one another. A firm without qualified staff cannot develop technical capabilities; without technical capabilities, knowledge transfer mechanisms remain ineffective; and without a solid knowledge base, firms cannot critically evaluate or adopt new practices. This interdependence means capability barriers create a cycle of stagnation that is difficult to break. What stands out here is that the problem is not merely resource scarcity but also the failure to institutionalise long-term capability building. Addressing this factor therefore requires a sustained approach: embedding training and knowledge transfer within organisational strategy, aligning education with industry needs, and ensuring that clients, not just contractors, have the literacy to stimulate innovation. Without this, construction firms risk perpetually lagging behind technological developments, with each new wave of innovation deepening the divide between what is possible and what is actually achieved.

Factor 3 Structural Barriers

Structural barriers represent another major hindrance to construction innovation, explaining 13.67% of the total variance in this study. Unlike organisational or capability barriers, which are more internal to firms, structural barriers are embedded in the wider configuration of the industry, including its procurement frameworks, project organisation, and network relationships. These barriers persist not because firms are unwilling to innovate, but because the structures within which they operate restrict opportunities for sustained knowledge transfer, long-term investment, and collaborative experimentation. The structural setup of the industry reinforces a cycle where innovation remains incidental and fragmented rather than systemic and continuous.

A key challenge is the fragmentation of the industry, which creates silos between stakeholders and hinders the collective pursuit of innovation. Akintoye, Goulding and Zawdie (2012) show how this fragmentation disrupts collaboration and knowledge exchange, while Rose, Manley and Widen (2019) emphasise that the multi-firm production model leads to disjointed networks that fail to capture cumulative innovation. The issue lies not only in fragmentation itself but also in how project structures institutionalise short-term and transactional relationships that discourage continuity. Lessons learned often remain "project-bound" and rarely contribute to sector-wide capability building, which represents a lost opportunity for scaling innovation.

Another significant structural barrier is the persistence of traditional procurement systems, especially lump-sum contracts. Studies consistently highlight how these arrangements prioritise cost competition over long-term value (Blayse & Manley, 2004; Wei & Lam, 2014). By transferring risk disproportionately to contractors, such systems discourage experimentation and reinforce adversarial dynamics between stakeholders. Even when firms are technically capable and organisationally prepared to innovate, procurement structures make innovation financially unattractive or even risky. This reveals a structural contradiction: the industry claims to value innovation for productivity and sustainability, yet its dominant procurement models systematically undermine it. A shift toward value-based and collaborative procurement could therefore play a transformative role in unlocking innovation potential.

The temporary nature of projects further compounds these structural barriers. Research highlights how project coalitions disband once a project is complete, leading to knowledge discontinuities and organisational memory loss (Blayse & Manley, 2004; Maghsoudi, Duffield & Wilson, 2016). Hardie (2010) also notes that short-lived project teams weaken coordination and limit opportunities to embed new practices into long-term routines. Project-based transience not only restricts knowledge retention but also creates a mindset of short-term delivery at the expense of long-term improvement. Firms often see little incentive to invest in innovation if its benefits cannot be realised beyond a single project cycle. Digital platforms and integrated project delivery models could help mitigate these weaknesses by creating continuity across projects, but such approaches are still not widespread.

Taken together, these barriers show that innovation in construction is not merely a matter of organisational willpower or technical ability; it is deeply shaped by the structural frameworks that govern the industry. Fragmentation, adversarial procurement, and project transience collectively create a system where even the most capable and motivated firms struggle to sustain innovation. Overcoming these barriers requires not just firm-level strategies but systemic reforms that promote continuity, collaboration, and value-based practices. Without such structural transformation, innovation risks remaining peripheral, adopted in pockets but never diffused broadly across the sector.

Factor 4: Behavioural Barriers

Behavioural barriers account for 9.79% of the total variance in this analysis, reflecting how individual and collective attitudes within the construction industry obstruct the uptake of innovation. Unlike structural or organisational challenges, these barriers are more deeply rooted in human behaviour, like fear, resistance, and short-termism, which can undermine even the most supportive policies or technical capabilities. Behavioural barriers matter because they directly shape decision-making, influencing whether stakeholders embrace or resist change.

A central behavioural barrier is the fear of change, which creates hesitation and resistance across multiple levels of the industry. Arayici, Khosrowshahi, Farzad Ponting and Mihindu (2009) illustrate how reluctance to adopt new workflows and reluctance to train staff reflect a deep-seated adherence to traditional methods. This conservatism is echoed by Gambatese and Hallowell (2011), who note that clients, especially intergovernmental organisations, often resist transformative innovation. Owolabi et al. (2019) further demonstrate how cultural aversion to change ranks as a top barrier in developing economies, showing that the problem is not simply technical but behavioural. What makes this especially problematic is that innovation is inherently disruptive; resistance, therefore, directly undermines the possibility of systemic improvements. Addressing fear of change requires more than policies, it calls for active cultural reorientation, trust-building, and demonstrating the tangible benefits of innovation in practice.

Another key behavioural barrier is the project-based production mindset, which emphasises short-term delivery over long-term learning. Akintoye, Goulding and Zawdie (2012) describe how temporary project coalitions limit the retention of knowledge, while Blayse and Manley (2004) stress that one-off projects disrupt organisational memory. Davidson (2013) and Lenderink et al. (2020) show that this short-termism weakens incentives to pursue systemic innovation, since investments cannot be recovered across a fragmented set of projects. This is reinforced by Wei and Lam (2014), who observe that short-term planning horizons strain budgets and deprioritise innovation. Importantly, the behavioural dimension here lies not only in structural constraints but in the collective mindset that accepts short-term outcomes as the norm. Breaking away from this requires leadership that reframes projects as opportunities for cumulative learning, supported by systems that preserve and transfer knowledge across projects.

The preference for quick pay-off opportunities further exemplifies the behavioural inclination toward short-term results. Akintoye, Goulding and Zawdie (2012) note that firms prioritise immediate gains over long-term innovation, while Tatum (1989) explains that client demands for cost-effective solutions drive contractors to favour inexpensive, low-risk approaches. This tendency reinforces dependence on established practices and creates inertia against more transformative approaches. The challenge is not just financial but behavioural, stakeholders are conditioned to expect fast returns, and this shapes risk-averse strategies. Encouraging long-term investment horizons, possibly through procurement reform or incentive schemes, is crucial to overcoming this barrier.

Taken together, behavioural barriers highlight how deeply ingrained attitudes, such as fear of change, project-focused short-termism, and preference for immediate payoffs, collectively discourage innovation in the construction sector. These behaviours are self-reinforcing: fear leads to conservatism, which strengthens the short-term focus, which in turn reduces willingness to take risks. Overcoming behavioural barriers, therefore, requires both cultural transformation within organisations and structural incentives that reward patience, collaboration, and long-term improvement. Unless these behavioural tendencies are addressed, even well-designed structural reforms and technological advances may fail to achieve their intended impact.

Factor 5: Temporal-Risk Barriers

Temporal–risk barriers account for 9.11% of the total variance in this study, underscoring the dual challenge of tight project timelines and pervasive risk aversion in the construction industry. These forces combine to suppress innovation by limiting the time available for experimentation while simultaneously discouraging firms from embracing new technologies or processes. What makes this combination particularly restrictive is that time pressure amplifies risk sensitivity—when projects are constrained by strict deadlines, stakeholders are less willing to experiment with unfamiliar approaches, reinforcing reliance on conventional practices.

Time constraints are one of the most persistent temporal barriers. As Ozorhon, Oral and Demirkesen (2016) explain, strict schedules and budget limitations obstruct experimentation, especially in smaller firms where limited resources make innovation appear secondary. Hardie (2010) highlights that SMEs struggle with the lengthy testing and development cycles needed for new technologies, while Ratana Singaram et al. (2023) emphasise that adopting Construction 4.0 tools like BIM requires additional training, further straining already tight schedules. Rose, Manley and Widen (2019) note that such pressure pushes contractors toward conservative strategies, and Wei and Lam (2014) show that short project timelines significantly reduce appetite for innovation. These findings suggest that time scarcity does not simply delay innovation, it actively reshapes priorities, pushing firms to deprioritise creative exploration in favour of predictable delivery. This reflects a behavioural tendency within the industry to treat time as a constraint to be managed rather than as a resource to be strategically leveraged for innovation.

The complexity and scale of projects adds another temporal dimension, as coordination and communication challenges multiply with project size. While Ariono, Wasesa and Dhewanto (2022) argue that large projects sometimes enable BIM adoption due to stronger efficiency incentives, Blayse and Manley (2004) and Davidson (2013) highlight how intricate coordination demands often result in fragmentation and hinder systemic innovation. Lenderink et al. (2020) further argue that the scale and long lifespans of major projects increase investment risks, making radical innovations harder to justify. This indicates a paradox: larger projects may have the resources to support innovation, but their inherent complexity can create risk conditions that discourage experimentation. Integrated delivery approaches like design-build or alliancing have the potential to counterbalance this effect, but their adoption remains uneven across the industry.

The risk of failure further compounds temporal pressures. As Gambatese and Hallowell (2011) and Giel and Issa (2013) show, firms are reluctant to invest in untested ideas due to uncertainty about returns, particularly when costs are high and benefits unclear. Rose, Manley and Widen (2019) highlight disputes between clients and suppliers over who should shoulder the risk of failed innovations, which frequently stall adoption. Wei and Lam (2014) note that traditional contracts intensify these risk conditions, discouraging contractors from experimenting with new approaches under the threat of financial penalties or delays. Arayici, Khosrowshahi, Farzad Ponting and Mihindu (2009) reinforce this by showing how UK firms view BIM's costs as outweighing potential benefits. Together, these findings show that risk aversion is not simply a rational financial calculation—it is also an entrenched cultural norm that reinforces short-termism and discourages bold innovation.

Collectively, temporal–risk barriers create a reinforcing cycle: limited time encourages conservative strategies, while risk aversion further reduces willingness to experiment, leaving little room for long-term innovation. Overcoming these barriers requires systemic reforms, such as procurement models that reward innovation-friendly timelines and shared risk frameworks, but it also requires a cultural shift. When time is reframed not as a constraint but as an opportunity for learning, and when risk is managed collaboratively rather than offloaded, the industry is better positioned to sustain innovation even under demanding project conditions.

4.10 Future Prospects for Construction Innovation in Malaysia

Figure 4.9 illustrates respondents' views on Malaysia's progress in adopting construction innovation relative to other countries. A combined total of 55.33% of respondents believed Malaysia is on par with other countries, while 44.67% perceived the country to be behind. Notably, none of the respondents considered Malaysia to be ahead, indicating a clear perception that Malaysia is not leading in construction innovation.

This perception is consistent with previous research highlighting the structural and institutional barriers that hinder innovation in Malaysia's construction industry. Challenges such as insufficient investment in research and development, slow regulatory reforms, and a conservative industry mindset have been frequently cited as impediments to progress (Olanrewaju and Abdul-Aziz, 2015; CIDB, 2022).

The absence of any perception that Malaysia is ahead of its international counterparts underscores the urgent need for strategic policy interventions and industry-wide transformation. Without deliberate efforts to promote the adoption of advanced construction technologies and practices, Malaysia risks falling further behind global leaders in innovation (Azman *et al.*, 2010; Aibinu and Venkatesh, 2014).

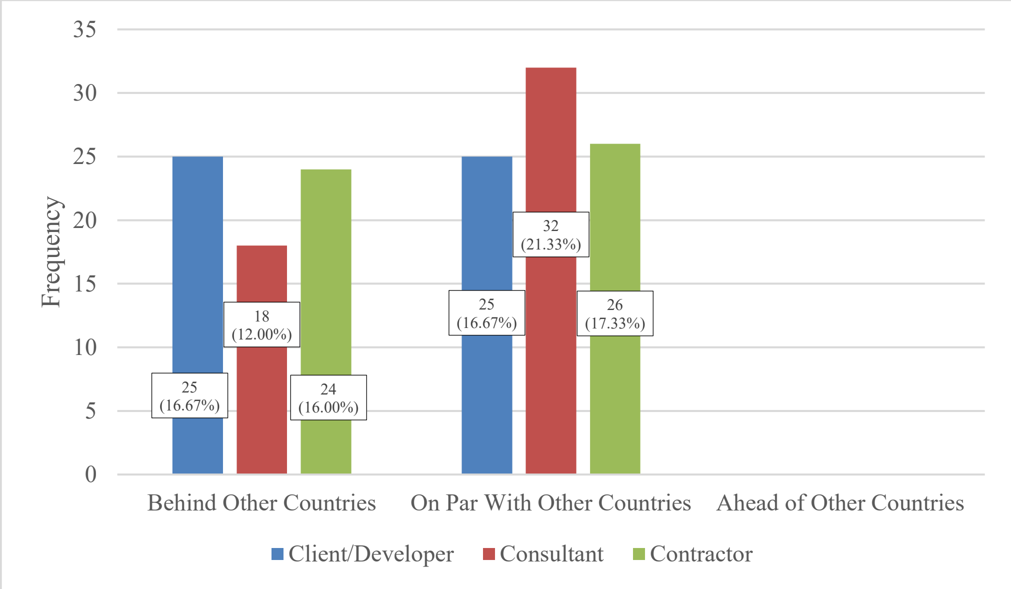

Figure 4.9: Rating of Malaysia's Progress in Adopting Construction Innovation Compared to Other Countries.

Figure 4.10 illustrates respondents' perceptions regarding the impact of innovation adoption on the competitiveness of the Malaysian construction industry. A significant majority, 64.67%, agreed that innovation enhances competitiveness, while a further 28.67% strongly agreed. Combined, 93.34% of respondents expressed a positive view, indicating a broad consensus across the industry. In contrast, only 5.33% of respondents were neutral, and a minimal proportion expressed disagreement, with 0.67% selecting disagree and another 0.67% selecting strongly disagree.

Contemporary evidence supports this perception, with the CIDB emphasizing that the integration of advanced technologies, such as BIM, automation, and digital construction tools substantially improves productivity, operational efficiency, and project delivery outcomes (CIDB, 2022). Similarly, recent research by Gerami and Gerami (2025) demonstrates that digitalization and innovation contribute to significant reductions in project timelines and costs, while simultaneously enhancing quality, thereby strengthening competitive positioning.

The data suggests that fostering innovation adoption is not only widely supported but is also viewed as essential to enhancing the overall competitiveness of the Malaysian construction industry in an increasingly globalised market.

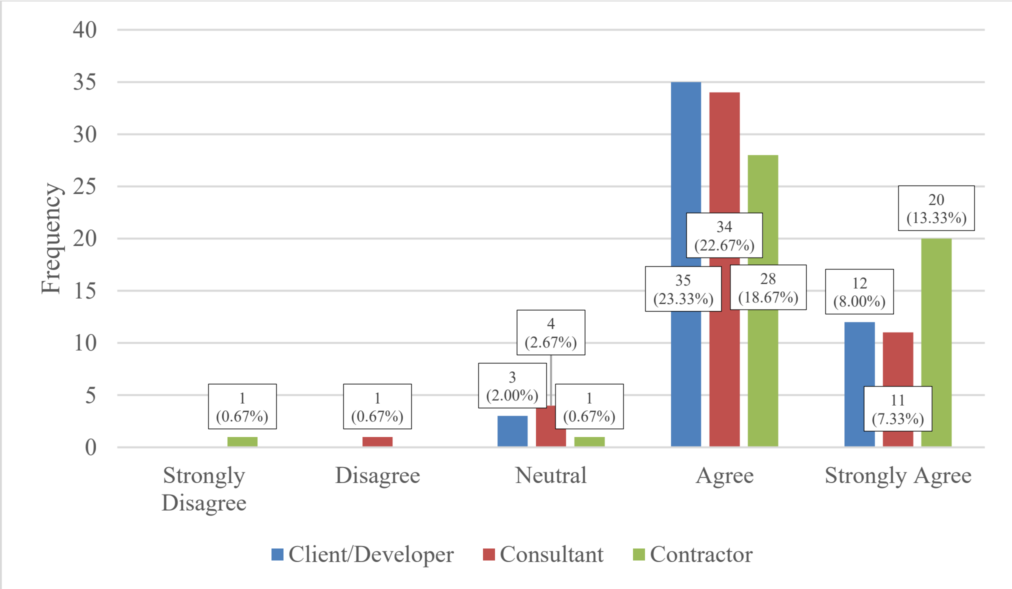

Figure 4.10: Agreement on the Impact of Innovation Adoption on Competitiveness of Malaysia's Construction Industry.

The findings shown in Figure 4.11 indicate that the Malaysian construction industry exhibits a moderate level of readiness to embrace innovation over the next five to ten years. The majority of respondents, approximately 78.00%, categorised their organizations as either Somewhat Prepared or Prepared, reflecting an emerging recognition of the importance of innovation but limited substantive integration within current operational practices.

Only a minority of respondents, around 16.67%, identified as Very Prepared or Fully Prepared, which underscores persistent challenges such as risk aversion, constrained financial resources, insufficient investment in research and development, and fragmented stakeholder collaboration. Such barriers have been substantiated by recent studies, which additionally underscore systemic impediments such as inadequate digital leadership, lack of comprehensive regulatory frameworks, and skills deficits impeding digital transformation efforts (CIDB, 2020; Abdul-Samad *et al.*, 2024; Nasir, Sahidi and Hasim, 2024). The relatively low proportion of stakeholders indicating a complete lack of preparedness, approximately 5.33%, suggests that while outright resistance to innovation is minimal, there remains a significant gap between awareness and actionable readiness.

These results corroborate earlier findings on the critical role of strategic policy interventions, financial incentives, capacity-building programs, and enhanced collaboration across the construction ecosystem to elevate industry readiness (CIDB, 2020). Therefore, enhancing the industry's readiness requires deliberate interventions such as policy support, financial incentives, capacity-building programs, and strengthened collaboration across the construction value chain.

In summary, the moderate readiness observed signals an urgent need for concerted efforts to advance innovation capabilities, ensuring the Malaysian construction industry remains competitive and sustainable in an increasingly dynamic and technology-driven global environment.

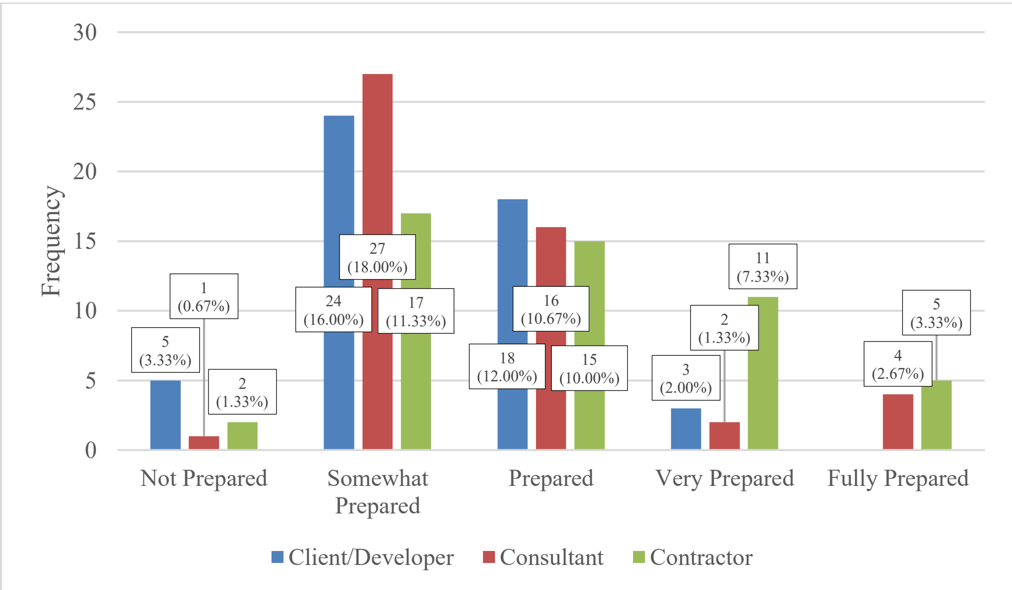

Figure 4.11: Readiness of the Malaysian Construction Industry to Support Innovation in the Next 5-10 Years.

Moving on, the findings regarding the likelihood of organisations allocating additional resources to construction innovation over the next five years demonstrate a cautiously optimistic industry outlook, as shown in Figure 4.12. Over half of the respondents, approximately 58.00%, indicated a positive disposition by selecting Likely or Very Likely, while a notable proportion (34.00%) remained Neutral. This suggests a growing recognition of the importance of resource commitment in driving innovation, yet also reflects some degree of uncertainty among stakeholders.

When considered alongside the earlier results on innovation readiness, where the majority identified as Somewhat Prepared or Prepared but only a small fraction felt Very Prepared or Fully Prepared, this pattern suggests that the industry is in a transitional phase. The moderate readiness to support innovation appears to correspond with a tentative but increasing willingness to allocate resources toward innovative initiatives.

However, the prevalence of neutral responses and a minority (8.00%) expressing reluctance indicate that barriers such as financial limitations, risk perceptions, and unclear innovation outcomes continue to temper full commitment. These challenges have been noted in prior research as significant impediments to innovation investment in construction (Rogers, 2015; Figenschou *et al.*, 2024).

Overall, the linkage between moderate preparedness and measured resource allocation intentions highlights a critical juncture for the Malaysian construction industry. Targeted strategies that enhance confidence in innovation benefits, provide financial incentives, and foster collaboration are essential to translate readiness into tangible investment and sustained innovation performance (CIDB, 2020).

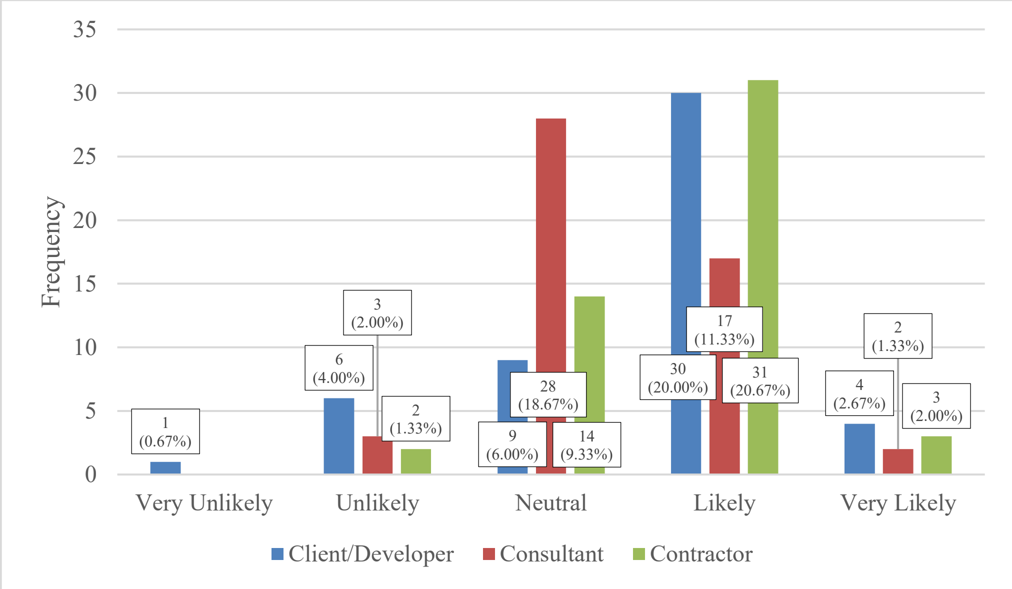

Figure 4.12: Likelihood of Organisations Allocating More Resources to Construction Innovation in the Next 5 Years.

Building on the findings concerning the industry's readiness to support innovation and its willingness to invest, respondents' perceptions reveal an important connection to the broader adoption of construction innovation as standard practice. Notably, 77.33% of participants indicated optimism that innovation will become normalised within the Malaysian construction industry over the next decade, rating it as either Likely or Very Likely. This strong majority highlights a positive association between resource commitment and the expectation that innovative practices will increasingly be embedded into industry norms.

However, the presence of 20.00% of respondents adopting a Neutral stance and 2.67% expressing Unlikely suggests that optimism is not yet universal. These results indicate that although the importance of innovation is widely recognised, substantive challenges remain before full institutionalisation can be achieved. Key obstacles include entrenched cultural resistance, shortages of skilled personnel, and insufficient policy incentives to support sustained investment and knowledge sharing (CIDB, 2022; Figenschou *et al.*, 2024).

Taken together, the findings portray the Malaysian construction sector at a critical juncture. Moderate readiness, a cautious yet growing intent to allocate resources, and a prevailing belief in innovation's eventual normalisation all point to a transitional phase. For innovation to progress from an emerging priority to an established norm, coordinated strategies involving industry leadership, policy frameworks, and workforce development will be essential to overcoming persistent impediments and cultivating an enabling environment for continuous innovation.

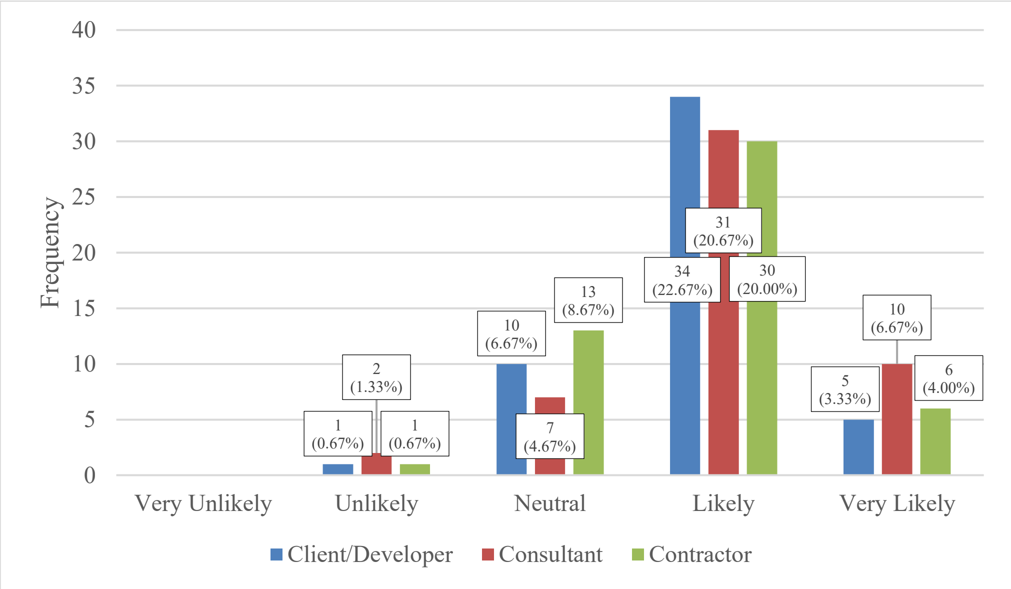

Figure 4.13: Likelihood of Construction Innovation Becoming Standard Practice in the Malaysian Construction Industry Within the Next Decade.

4.11 Summary

Chapter 4 presents a comprehensive analysis of the survey data regarding drivers and barriers of construction innovation in Malaysia, offering critical insights into industry perceptions and underlying factors influencing innovation adoption. The findings reveal a broad consensus on the necessity and positive impact of construction innovation, alongside recognition of the pivotal role played by both drivers and barriers. The respondent profile, distinguished by balanced stakeholder representation and varied experience levels, supports the robustness and generalizability of the results.

Reliability and normality assessments confirm the appropriateness of the data for rigorous statistical analyses, with non-parametric tests employed due to non-normal distributions. The identification and ranking of key innovation drivers highlight the significance of technology push, sustainability considerations, technological capability, strategic alliances, and subsidies in shaping innovation dynamics within the Malaysian context. Conversely, financial constraints, resource gaps, technical capability deficits, lack of incentives, and legislative inadequacies emerge as dominant barriers impeding innovation progress.

Factor analyses further consolidate these drivers and barriers into coherent thematic groups, elucidating complex interrelations between institutional, organisational, market, technological, behavioural, and temporal dimensions. Statistically significant differences in perceptions among clients, consultants, and contractors underscore the necessity for stakeholder-sensitive policies and targeted interventions to effectively enhance innovation uptake. Moreover, the analysis of future prospects indicates a cautiously optimistic industry stance, with moderate readiness and measured commitment to resource allocation tempered by persistent systemic challenges.

Collectively, the results underscore the multifaceted nature of construction innovation in Malaysia, shaped by an intricate interplay of internal capacities, external pressures, and structural conditions. These findings provide a solid empirical foundation to inform tailored strategies and policy frameworks aimed at fostering a more conducive innovation ecosystem. Addressing the identified barriers while leveraging the critical drivers through coordinated industry and government efforts will be essential to propel Malaysia's construction sector toward sustained competitiveness, environmental responsibility, and global relevance.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This final chapter synthesises the findings of the preceding research, drawing comprehensive conclusions regarding the drivers and barriers influencing construction innovation in Malaysia. It reflects on the broader implications of these insights for industry stakeholders, policymakers, and researchers. By addressing the research objectives and providing a balanced evaluation of the study's contributions and limitations, this chapter sets the stage for informed recommendations aimed at fostering innovation within Malaysia's construction sector. The concluding remarks accentuate the study's significance in the context of Malaysia's socio-economic development and the global shift toward sustainable, technology-driven construction practices.

5.2 Conclusion

This study was undertaken to investigate the drivers and barriers of construction innovation in the Malaysian construction industry. By combining an extensive literature review with a structured survey of 150 practitioners involving developers, consultants, and contractors in the Klang Valley region, the research provides comprehensive insights into the dynamics shaping innovation in Malaysia. Rigorous statistical tests were performed to ensure the robustness of the analysis. The Cronbach Alpha's reliability test confirmed strong internal consistency across both the drivers and barriers of construction innovation, while the Shapiro-Wilk test indicated non-normal distribution, justifying the use of non-parametric analyses. The suitability of the dataset for factor analysis was further established through the Kaiser-Meyer-Olkin (KMO) measure, which exceeded the recommended threshold of 0.6, and Bartlett's Test of Sphericity, which returned statistically significant results at $p < 0.001$. These results validated the dataset for deeper multivariate analysis and ensured the credibility of the findings.

Objective 1:

The first objective of this study was to identify the key drivers of construction innovation in Malaysia. The analysis reveals that technology push, environmental sustainability, technological capability, strategic alliances, and subsidies represent the most critical drivers, reflecting both global industry trends and local priorities. These drivers underscore the dual influence of technological advancement and sustainability imperatives, supported by financial and institutional mechanisms that lower adoption risks. The statistical results, particularly from the Kruskal–Wallis test, further highlight that perceptions of these drivers vary significantly across stakeholders. Contractors tend to prioritise operational enablers such as training, absorptive capacity, R&D, and subsidies, reflecting their reliance on workforce competence and external financial support. By contrast, consultants and government agencies emphasise systemic integration through technological capability, fusion, and regulatory frameworks, while developers focus more on financial and managerial considerations, often placing less weight on regulation and operational drivers.

Objective 2:

The second objective was to examine the barriers hindering construction innovation in Malaysia. The analysis reveals that the five most critical barriers to construction innovation comprise financial and resource-related constraints, namely the lack of financial resources, operational resource gaps, and lack of technical capability, alongside institutional barriers such as lack of incentives and inappropriate legislation. These findings reinforce long-standing concerns that innovation depends not only on capital investment but also on organisational readiness, skilled human resources, and supportive institutional frameworks. In Malaysia, where the construction sector is dominated by SMEs, financial and capability-related barriers are particularly acute, as limited funding and expertise constrain the ability of firms to adopt advanced technologies. At the same time, the prominence of inadequate incentives and inappropriate legislation underscores weaknesses in policy design, where current frameworks fail to provide sufficient motivation or regulatory clarity to stimulate innovation. Collectively, these barriers reveal how financial, operational, and institutional deficiencies converge to restrict the sector's transformative potential. Results from the Kruskal–Wallis test provide further nuance, showing statistically significant differences across stakeholder groups. Contractors expressed the strongest concerns regarding financial pressures, resource shortages, and capability gaps, reflecting their immediate exposure to project execution challenges. Developers and consultants, by contrast, rated these barriers less critically, consistent with their relatively greater strategic leverage and access to resources. Divergence was also observed in perceptions of legislation, with contractors viewing regulatory frameworks as more restrictive than developers and consultants. These differences highlight that the burden of innovation barriers is unevenly distributed, shaped by the distinct functional roles and operational realities of industry stakeholders.

Objective 3:

On the drivers' side, six underlying factors were extracted, collectively explaining a substantial proportion of the variance. These factors are institutional and technological drivers, collaboration and market drivers, competition and complexity, sustainability and capacity, leadership and integration, and alliances and knowledge. Together, they demonstrate that innovation emerges from the interaction between external institutional support, evolving market dynamics, and firms' internal capabilities. Financial incentives, regulatory frameworks, and technological readiness provide the foundational conditions for innovation, while collaboration, leadership, and strategic alliances create the organisational and relational mechanisms necessary to sustain it. At the same time, market competition, evolving design practices, and sustainability imperatives act as external pressures that compel firms to pursue innovative solutions. These findings affirm that construction innovation is not driven by isolated forces but by systemic interactions that align institutional, market, and organisational dimensions.

In contrast, the analysis of barriers yielded five latent factors which collectively capture the principal constraints to innovation. These are organisational barriers, capability barriers, structural barriers, behavioural barriers, and temporal-risk barriers. Organisational and capability barriers expose firm-level weaknesses, including unsupportive cultures, insufficient incentives, and shortages of skilled personnel that limit readiness for technological adoption. Structural barriers highlight systemic challenges such as industry fragmentation, adversarial procurement practices, and the temporary nature of projects, all of which undermine long-term knowledge retention and collaborative learning. Behavioural barriers reflect entrenched attitudes, including resistance to change and a preference for short-term returns, while temporal risk barriers show how tight project schedules and heightened risk aversion suppress experimentation and reinforce reliance on conventional practices. Overall, this holistic analysis provides a structured understanding of where interventions should be prioritised.

Beyond these objectives, the study also examined stakeholders' perceptions of the future of construction innovation in Malaysia. Overall, respondents expressed a cautiously optimistic outlook on the future of construction innovation in Malaysia. While many viewed the industry as on par with international peers, none perceived it as leading, reflecting persistent financial, institutional, and cultural barriers. At the same time, there was a strong consensus that innovation is essential for competitiveness, with most organisations considering themselves somewhat prepared, though only a few felt fully ready. The majority also indicated a willingness to allocate more resources toward innovation, suggesting that the industry is in a transitional phase where awareness is high but full commitment remains tempered by uncertainty.

In conclusion, this study demonstrates that construction innovation in Malaysia is shaped by a complex interplay of drivers and barriers that operate across institutional, organisational, and market dimensions. While strong consensus exists on the importance of innovation for competitiveness, persistent financial, capability, and structural challenges continue to constrain progress. The findings highlight both the opportunities and the obstacles facing the industry, underscoring the need for coordinated efforts from policymakers, industry leaders, and practitioners to translate awareness and emerging readiness into sustained innovation and long-term transformation.

5.3 Research Implications

The findings of this study have significant implications for multiple facets of the construction industry in Malaysia and offer valuable guidance for practitioners, policymakers, and academics seeking to stimulate innovation. For industry practitioners, recognising technology push and environmental sustainability as leading drivers points to the urgent need for continuous investment in digital technologies and green construction practices. Firms must prioritise capability development, particularly through workforce training and integrated R&D functions, to harness emerging technological opportunities fully. The identification of strategic alliances and collaborative knowledge networks as critical drivers further implies that firms should actively seek partnerships to overcome resource limitations and access diverse expertise.

From a policy perspective, the central role of subsidies and performance-based regulations underscores the importance of maintaining and refining government support programs. These findings advocate for targeted financial incentives, especially for SMEs, which are less equipped to absorb innovation costs independently. Furthermore, the emphasis on regulatory frameworks highlights the necessity for legislative reforms tailored to digital technologies such as BIM and integrated procurement practices that incentivise innovation rather than impede it. Policymakers should also consider fostering environments that encourage experimentation and knowledge sharing across project boundaries.

Academically, this study enriches the understanding of construction innovation by validating a comprehensive conceptual framework that integrates institutional, organisational, behavioural, and temporal dimensions. The stakeholder-specific insights highlight the value of differentiated approaches in research and practice. Future academic inquiry may build on these results by exploring longitudinal impacts of innovation interventions, investigating behavioural and cultural transformation mechanisms, and assessing the scalability of technological innovations across varying project types and firm sizes. Beyond Malaysia, the study also offers transferable value to other developing countries facing similar structural, financial, and institutional challenges, providing a reference point for designing strategies that balance global innovation trends with local industry realities.

Beyond Malaysia, the study provides valuable insights for other developing countries facing similar structural, financial, and institutional challenges. It offers a reference point for designing strategies that balance global innovation trends with local industry realities, helping emerging economies to create a more resilient, competitive, and future-ready construction sector.

5.4 Research Limitations

Despite the comprehensive focus of this investigation, several limitations must be acknowledged to contextualise the findings appropriately and guide future research directions. Foremost among these is the reliance on a cross-sectional survey design, which captures perceptions at a single point in time. While this approach provides a valuable snapshot of prevailing views on innovation drivers and barriers, it inherently constrains the ability to infer causal relationships or track changes over time. Longitudinal studies would enrich understanding by revealing how these factors evolve in response to policy shifts, market developments, or technological diffusion.

Another limitation concerns the sampling framework, which, while purposefully designed to include a balanced representation of clients, consultants, and contractors within the Klang Valley, may not fully capture the diversity of experiences across Malaysia’s broader construction landscape. Regional disparities, varying firm sizes, and differing project types outside this urban centre could manifest distinct innovation dynamics that this study does not fully address. Additionally, the use of non-probability sampling techniques introduces risks of selection bias and limits the generalizability of results to the entire population of construction professionals.

Furthermore, the study’s quantitative methodology, focused on structured questionnaires and statistical analysis, prioritises breadth over depth. The exclusion of qualitative insights leaves unexplored the nuanced motivations, cultural factors, and organisational narratives that underpin innovation processes. A mixed-methods approach incorporating interviews or case studies could provide richer contextualisation and deeper explanatory power. Lastly, external environmental factors such as macroeconomic conditions or international competitive pressures, while acknowledged, were not the primary focus. Future research might integrate these broader influences to present a more holistic account of innovation challenges and opportunities.

5.5 Recommendations for Future Work

Building on the insights and limitations identified, several avenues for future research and practice are recommended to advance the understanding and facilitation of construction innovation in Malaysia. Firstly, longitudinal studies are crucial to track how innovation drivers and barriers fluctuate over time, particularly in response to technological advances and policy interventions. Such research would enable the assessment of cause-and-effect relationships and provide dynamic insights into the innovation lifecycle.

Secondly, expanding the geographic scope beyond the Klang Valley to include rural and other urban areas within Malaysia is recommended. This extension would capture regional heterogeneity in innovation experiences and barriers, enabling more inclusive policy design and industry support strategies. Studies focusing on different firm sizes and project types, including public infrastructure versus private developments, would yield granular findings tailored to specific segments.

Thirdly, integrating qualitative methods such as interviews, focus groups, and ethnographic observation could illuminate the cultural and behavioural underpinnings of innovation, complementing quantitative results. Investigating the role of organisational culture transformation, leadership practices, and employee engagement in innovation uptake would add valuable depth. Moreover, exploring the efficacy of collaborative platforms, training programs, and technology pilots through case studies could provide actionable lessons for scaling innovation.

Finally, future research should consider incorporating external factors such as economic cycles, global competition, and technological disruptions like artificial intelligence and blockchain within Construction 4.0 frameworks.

Evaluating how these elements interact with internal drivers and barriers would offer a comprehensive perspective essential for strategic foresight. Overall, these future directions aim to strengthen Malaysia's construction sector's innovation capacity, supporting its transition toward a more competitive, sustainable, and technologically advanced industry.

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APPENDICES

Appendix A: Questionnaire.

9/16/25, 11:16 PM INVESTIGATING THE DRIVERS AND BARRIERS OF CONSTRUCTION INNOVATION IN MALAYSIA

INVESTIGATING THE DRIVERS AND BARRIERS OF CONSTRUCTION INNOVATION IN MALAYSIA

Dear Sir/Madam,

Warm greetings to you. My name is Daniel Chang Xiau Yie, and I am a final year undergraduate student pursuing the **Bachelor of Science (Honours) in Quantity Surveying** at **Universiti Tunku Abdul Rahman (UTAR)**.

I am currently undertaking my **Final Year Project** entitled:

"Investigating the Drivers and Barriers of Construction Innovation in Malaysia"

This study aims to achieve the following research objectives:

1. To examine the key drivers that promote innovation in Malaysia's construction industry.
2. To evaluate the barriers that hinder innovation adoption within the industry.
3. To uncover the underlying factors that influence the success and challenges of innovation implementation in Malaysia's construction industry.

This questionnaire comprises four sections and is designed to be completed within approximately **10 minutes**. I would be sincerely grateful if you could spare some time to participate in this survey. Your insights and experience are highly valuable in contributing towards a better understanding of the current state of innovation in Malaysia's construction industry.

Please rest assured that all information provided will be kept **strictly confidential** and will be used **solely for academic purposes**.

Should you have any questions or require further clarification, please do not hesitate to contact me at **dcxy0523@1utar.my**.

Thank you very much for your time and support.

Yours faithfully,
Daniel Chang Xiau Yie
Final Year Student
Bachelor of Science (Honours) Quantity Surveying
University Tunku Abdul Rahman (UTAR)

* Indicates required question

Section A: General Information
**Tick only one choice per question*

1. 1. What is the nature of your organisation? *

Mark only one oval.

- Client / Developer
- Consultant
- Contractor

2. 2. How many years of working experience do you have in the construction industry? *

Mark only one oval.

- Less Than 5 Years
- 5-10 Years
- 11-15 Years
- 16-20 Years
- Over 20 Years

3. 3. What is your current position in the organisation? *

Mark only one oval.

- Executive
- Manager
- Senior Manager
- Top Management / Director

4. 4. What is your highest academic qualification? *

Mark only one oval.

- High School
- Diploma
- Degree
- Postgraduate Degree (PhD, Master's)

5. 5. What is the typical nature of the projects you are most involved in? *

Mark only one oval.

- Private Sector Projects
- Public Sector Projects

6. 6. What is the typical value range of the construction projects you are involved in? *

Mark only one oval.

- Less Than RM1 Million
- RM1 Million - RM10 Million
- RM10 Million - RM50 Million
- RM50 Million - RM100 Million
- Over RM100 Million

7. 7. To what extent do you agree that construction innovation is necessary to meet evolving industry demands and environmental standards? *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

8. 8. To what extent did the innovation address the targeted construction issues (e.g. cost, time, quality, safety)? *

Mark only one oval.

- No Improvement
- Slight Improvement
- Moderate Improvement
- Clear Improvement
- Major Breakthrough

9. 9. How important is it to assess the ***drivers*** of construction innovation in order to accelerate innovation uptake in the construction industry? *

Mark only one oval.

- Not At All Important
- Slightly Important
- Moderately Important
- Very Important
- Extremely Important

10. 10. How important is it to assess the ***barriers*** to construction innovation in order to accelerate innovation uptake in the construction industry? *

Mark only one oval.

- Not At All Important
- Slightly Important
- Moderately Important
- Very Important
- Extremely Important

Section B: Drivers of Construction Innovation

11. 11. Please rate the extent to which you agree that each listed item is a ***significant driver*** of construction innovation. Select only one response per item. *

Mark only one oval per row.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Empowerment of innovation champions/leaders					
Training					
Integrated and informal R&D function					
Absorptive capacity (refers to the ability of your organisation to recognise, understand, and apply new technology)					
Corporate responsibility					
Leadership					
Coordination of participating groups					
Creation of knowledge networks					
Strategic alliances (e.g. with suppliers, clients, or researchers to work together on innovative solutions)					
Programs promoting collaboration					
Market pull/client requirement					
Competition level					
Design trends					
Project complexity					
Technology push					
Integrated design-build					
Technology capability					
Technology fusion (e.g. combining different technologies to develop new solutions)					
Innovation stimulating regulations					
Project performance improvement					
Environment and sustainability					
Subsidies					

Section C: Barriers to Construction Innovation

12. 12. Please rate the extent to which you agree that each listed item is a ***significant barrier*** to construction innovation. Select only one response per item. *

Mark only one oval per row.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Unsupportive organisational culture	◯	◯	◯	◯	◯
Fear of change	◯	◯	◯	◯	◯
Lack of incentives	◯	◯	◯	◯	◯
Organisational rigidity	◯	◯	◯	◯	◯
Lack of recognition from clients	◯	◯	◯	◯	◯
Lack of financial resource	◯	◯	◯	◯	◯
Operational resource gap	◯	◯	◯	◯	◯
Preference for quick pay-off opportunities	◯	◯	◯	◯	◯
Limited innovation knowledge	◯	◯	◯	◯	◯
Lack of experienced and qualified staff	◯	◯	◯	◯	◯
Lack of technical capabilities	◯	◯	◯	◯	◯
Project-based production	◯	◯	◯	◯	◯
Temporary nature of projects	◯	◯	◯	◯	◯
Time constraints	◯	◯	◯	◯	◯
Complexity/scale of projects	◯	◯	◯	◯	◯
Risk of failure	◯	◯	◯	◯	◯
Inappropriate legislation	◯	◯	◯	◯	◯
Industry fragmentation	◯	◯	◯	◯	◯
Procurement systems (e.g., lump-sum contracts)	◯	◯	◯	◯	◯
Economic/political conditions	◯	◯	◯	◯	◯

Section D: Future Prospects for Construction Innovation in Malaysia

13. 13. Compared to other countries, how would you rate Malaysia's progress in adopting construction innovation within the construction industry? *

Mark only one oval.

- ◯ Ahead of Other Countries
- ◯ On Par With Other Countries
- ◯ Behind Other Countries

14. 14. To what extent do you agree that the adoption of innovation will significantly improve the competitiveness of Malaysia's construction industry in the future? *

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

15. 15. How well-prepared do you think the Malaysian construction industry is to support innovation over the next 5-10 years? *

Mark only one oval.

- Not Prepared
- Somewhat Prepared
- Prepared
- Very Prepared
- Fully Prepared

16. 16. How likely is it that your organisation will allocate more resources to construction innovation in the next 5 years? *

Mark only one oval.

- Very Unlikely
- Unlikely
- Neutral
- Likely
- Very Likely

17. 17. How likely is it that construction innovation will become a standard practice in the Malaysian construction industry within the next decade? *

Mark only one oval.

- Very Unlikely
- Unlikely
- Neutral
- Likely
- Very Likely