PLANNING MALAYSIA:
Journal of the Malaysian Institute of Planners
VOLUME 22 ISSUE 3 (2024), Page 104 – 117

MODULAR CONSTRUCTION SYSTEMS: A FOCUS ON DEVELOPING TECHNICAL EXPERTISE IN MALAYSIA

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Abstract

The Government has clearly put focus on MCS as the future of construction through the Construction 4.0 Strategic Plan (2021-2025) and National Construction Policy 2030. However, the implementation of MCS in Malaysia is still low due to lack of technical expertise. This study aims to explore the challenges and strategies in achieving sufficient technical expertise to drive construction players in adopting MCS. Exploratory interviews were conducted with MCS experts to obtain multiple views in enhancing technical expertise to implement MCS in construction business. Respondents were obtained through snowball sampling techniques by approaching expert personnel in MCS. Findings were then analysed using thematic analysis, discovering four main challenges that impede adoption of MCS and four aspects of strategies identified to enhance technical expertise in MCS. The exploratory nature of this study provides the preliminary indicators for future actions to drive the adoption of MCS in developing countries.

Keywords: Modular Construction System (MCS), Qualitative Interview, Challenges, Strategies

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INTRODUCTION

Modular Construction System (MCS) has emerged as a promising innovation to tackle the long-standing challenges of tight schedules, high costs, poor quality, disjointed supply chains, and limited sustainability practices in the construction industry (Yuslim et al., 2023). The Construction Industry Council (Construction Industry Council, 2018) defines MCS as a comprehensive approach that involves constructing integrated modules in a controlled prefabrication facility. These modules are then transported to the construction site for integration into the building structure. MCS presents a high degree of off-site construction, with as much as 95% of a building's components fabricated in factories (Hwang et al., 2018).

MCS is recognized as a promising solution for providing affordable housing, offering cost-effective and time-efficient alternatives to traditional construction (Khan et al., 2022). It's reliability in maintaining quality due to controlled manufacturing environments positions it as suitable for fast-track projects, addressing the high demand for timely construction (Aziz et al., 2019). Additionally, the adoption of MCS is viewed as a catalyst for a paradigm shift in the Industrialised Building System (IBS) industry, potentially solving affordable housing issues (Sidik et al., 2021). Current literature highlights the dual nature of MCS in Malaysia, emphasizing its potential for addressing housing needs while acknowledging and addressing associated challenges. One of the most commonly cited constraints in the construction sector is the lack of technical knowledge (Mohammad et al., 2016).

Developed nations like the United States, the United Kingdom, and Sweden have made significant policy strides in implementing MCS (Ferdous et al., 2019). Several developing nations, including Malaysia and Singapore, have put in place government regulations and incentive programs to encourage private developers to embrace MCS, as pointed out by Wuni & Shen (2019).

The primary obstacle to MCS adoption is the lack of understanding of the MCS business model (Cheng et al., 2017). This lack of knowledge extends to insufficient skills in MCS project inspection and limited experience in designing and installing modular components (Luo et al., 2015). A crucial aspect of realising the potential of MCS in the construction industry is the development of technical ability.

The successful implementation of MCS depends on the development of technical expertise, which is currently lacking in many developing countries, including Malaysia. This study aims to generate preliminary information to enhance technical expertise in MCS in Malaysia. The objectives are to explore the challenges in developing technical expertise for MCS and to identify the strategies to enhance the adoption of MCS. This study focuses on the Malaysian construction industry while the outcomes can be relevant and applicable to other

developing countries as well. A qualitative research approach was employed involving construction professionals in the field.

METHODOLOGY

Semi-structured interview was used for this study. It uses a set of predetermined open-ended questions where order and wording of questions are flexible, allowing for follow-up questions and exploration of new ideas (Mashuri et al., 2022) to strike a balance between the flexibility of unstructured interviews and the focus of structured ones. In this study, MCS contractors in the Malaysian construction market were the subjects of interviews. The interview started in April 2023 and went on for 3 months until it reached 10 respondents. Due to the unavailability of a database on MCS experts or projects in Malaysia, snowball sampling was used to gather respondents. It started by selecting an initial individual that meets the relevant criteria which are designated construction professionals working in an MCS contractor organization and having more than 5 years' experience working in the industry. Respondents were then asked to provide referrals of anyone they know who fits the study criteria. This leads the interview to other respondents, creating a snowball effect as new participants are added to the sample (Mohamed et al., 2019).

As time was of the essence, contractors were selected as the research focus. All respondents had been assured of the confidentiality of their identity and responses. Duration of each interview is set to 30 minutes and researchers stopped collecting data as the result became saturated, where new information becomes redundant, signalling its endpoint. Table 1 provides an overview of respondents' profiles.

To record the analysis of the data, codes are allocated to words and phrases from the data collection. As a result, the topic may be quantified, making it simpler to interpret and summarise the interview data. This study uses inductive coding since predetermined codes could introduce biases.

RESULTS AND ANALYSIS

Challenges

Challenges in developing technical expertise are outlined in Table 1. The analysis revealed four distinct themes emerged: (1) Lack of Experience, (2) Lack of Information, (3) High Costs, and (4) Unfamiliar Design.

Table 1: Challenges in developing technical expertise for MCS

Theme	Challenges	Respondents										Total
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
Lack of experience	Unwillingness to learn	/				/			/	/	/	5
	Uncommon method	/						/				2
	Afraid to take risk		/	/			/			/		4
Lack of knowledge and understanding	Narrow knowledge among parties			/	/		/			/		3
Cost	Costly BSI codes		/									1
	High capital cost	/		/	/	/			/		/	6
Complex design	Multiple components and difficult shape							/		/		`2

As mentioned by Yusof et al. (2023), unwillingness to learn presents a significant challenge. This is attributed to a traditional mindset, lack of awareness, fear of the unknown, and perceived risks associated with this innovative construction method (Wuni et al., 2023). Majority of the respondents established that stakeholders hesitated to invest in training and change management processes required for modular construction. This reluctance had also resulted in missed opportunities for cost savings, increased construction timelines, and limited innovation in the construction sector. The findings significantly tie to the literature by Ismail et al. (2022) that stated MCS requires substantial initial cost in developing human capital before the industry can maximise its benefits.

Two respondents acknowledged that MCS being the uncommon method, significantly hampers the growth of expertise in the area. It then resulted in the lack of local skills, limited supplier base, and regulatory misalignment. The issue had been addressed by Aziz et al. (2022), adding that inexperience can result in cost overruns, project delays, and reduced competitiveness. Wuni et al. (2023) also illustrated the crucial need for experienced personnel as MCS demands such a high degree of accuracy and precision in the assembly of the modules. Respondents further highlighted that the uncommon state of MCS has led to risk aversion attitude among industry players as stakeholders only prefer methods they are familiar with, coinciding with Ambartsumyan et al. (2023).

R3 and R1 added that many stakeholders are not fully aware of the benefits of MCS. Malaysia has a long history of traditional construction methods, and many construction professionals and companies are only confident with traditional practices. The situation is exacerbated by the lack of formal education and training related to MCS, leading to a chain of impacts which are low adoption rate, inaccessible modular material and services as well as rising costs. The issue

had been discussed eight years ago by Aziz & Abdullah (2015), addressing the significance of focusing on growth of knowledge in MCS. Current study by Yusof et al. (2023) indicated the situation still persists within the industry and stakeholders.

R2 mentioned the high cost of acquiring British Standards Institution (BSI) codes and standards. It is worth noting as the challenge had been discussed in detail relative to other types of construction (Gunasagaran et al., 2022). While some standards are made freely available to the public, many key standards, especially those relevant to specific industries, are proprietary and require purchase. This creates a barrier for smaller businesses, start-ups, or projects with limited budgets, hindering their ability to adhere to best practices in modular construction. The perceived technical incapability has led to some organisations opting not to purchase the standards to avoid non-compliance to the guidelines.

The high capital cost is a well-accepted challenge among respondents. R8 and R10 stated that due to the high initial cost, the MCS has then led to limited market penetration as smaller companies find it challenging to invest in MCS and therefore reducing competitiveness as MCS projects struggle to compete with traditional construction methods in terms of pricing. The findings are parallel with Arowoiya & Oyefusi (2023), which specified that MCS are often used for fast-track projects, therefore client has to put significant investment in starting the project and reap the reward later as the project saves time, cost of labour, overhead, and machineries rental and subcontracting.

R7 stated the complex architectural designs can be challenging to replicate in modular components. The unique designs require customisations that go against the principles of standardisation and repetition inherent in modular construction. It corresponds with the fact asserted by Wuni et al. (2023) that MCS heavily relies on the prefabrication and assembly of standardised building components in an off-site factory, the designs become complex or unconventional and thus pose several difficulties. MCS also has specialised structural requirements, such as heavy loads, seismic considerations, or building heights, which can make modular construction more challenging. R9 stressed on the complicated Mechanical, Electrical, and Plumbing (MEP) systems in MCS. The integration of MEP systems in MCS requires extra effort and customisation compared to conventional construction. R9 also emphasised on the site access constraints. MCS projects often involve tight or irregularly shaped sites which limit the flexibility of the modules to enter, hence, the high transportation cost.

Upon the study of data collected, three significant challenges had been identified: Stakeholders' unwillingness to learn, risk averse attitude, and high capital cost. The findings are positively correlated to multiple latest academic literature especially by Wuni et al. (2023) and Yusof et al. (2023). There are four other challenges that are equally important despite having fewer mentions among the interview respondents.

Strategies

Strategies to develop technical expertise for MCS are outlined in Table 2. The analysis revealed three themes: (1) Education empowerment, (2) Experience enhancement, and (3) Government initiatives.

Table 2: Strategies to develop technical expertise for MCS

Theme	Challenges	Respondents										Total
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
Education empowerment	Increase training/ course	/		/	/	/	/	/		/	/	8
	Upgrade education for next generation		/	/			/	/		/		5
	Increase public awareness			/	/	/			/	/		5
	Strengthen R&D	/	/			/	/				/	5
	Sharing knowledge			/	/	/		/	/	/		6
Experience enhancement	Intensify on-site experience			/	/	/	/	/		/	/	7
	Integrate Players from Different Companies	/			/	/			/	/		5
Government initiatives	Develop Modular Guideline	/		/	/	/						4
	Provide incentives for Sustainable Practices		/	/			/		/		/	5
	Elevate infrastructure				/		/	/			/	4

Most respondents emphasised the importance of improving training and educational courses as an effective strategy to enhance the skills of various stakeholders in the construction industry. According to Undang et al. (2022), this includes design principles, manufacturing processes, and assembly techniques, to boost the confidence of industry players in practising MCS. Some respondents mentioned the value of providing hands-on experience and sharing knowledge about Building Codes and Regulations, as well as quality management in MCS. A few building regulations had been established to ensure validity building of design and construction, for instance are the Uniform Building By-Laws (UBBL), Street, Drainage, and Building Act 1974 (Act 133), National Building Code (NBC), Environmental Quality Act 1974, Town and Country Planning Act 1976 and Fire Services Act 1988 by the Fire and Rescue Department of Malaysia. Bello et al. (2023) have stated that the laws and regulations need to be in harmony with the MCS growth to ensure productive progress of the necessary expertise. Majority of the respondents agree that offering training and courses focused on MCS can significantly aid its expertise development which coincides with Teh & Zainal (2021).

In addition to training and courses, respondents recommended integrating MCS knowledge into academic curricula. This would expose students

in universities, technical schools, and vocational institutions to MCS concepts, principles, and techniques. It relates to Liu et al. (2022) about the importance for future generations to understand sustainable practices and the application of modular construction to reduce waste and improve energy efficiency. Respondents also suggested launching mass media campaigns to address misconceptions about MCS quality, safety, and showcase its benefits such as speed, cost-efficiency, and sustainability. Successful MCS projects can be showcased to demonstrate its success as the future construction method. One respondent, R8, even suggested building such projects in prominent locations visible to the public to allow first-hand observation. The goal is to overcome the negative perception of MCS as costly, risky, and resistant to renovation, which hinders its skills growth as illustrated by Cynthia Hou et al. (2023). People need to recognise the global growth of modular systems in building construction and the advantages they offer to motivate investment in developing technical expertise (Loo & Wong, 2023).

Furthermore, five respondents highlighted the importance of contemporary research and development (R&D) in promoting MCS adoption. As per Ribeiro et al. (2022), construction demands vary by country, hence the need for researchers to innovate advanced building materials, digital modelling tools, and automation in modular construction processes. Respondents proposed various other recommendations related to R&D, such as standardising MCS practices, continuous improvement, prototyping, risk identification, case studies, industry-academic collaboration, and quality enhancement, all of which can be achieved through a strong focus on national R&D. The opinions coincide with Ambartsumyan et al. (2023) indicating that design must be adapted to suit MCS implementation.

After acquiring new knowledge, knowledge sharing becomes crucial for empowering individuals and industry players' expertise in adopting MCS. Respondents suggested organising seminars and workshops for industry professionals, including architects, engineers, contractors, and developers. They also emphasised information dissemination through webinars and online resources. Khan et al. (2022) asserted that knowledge sharing programs enable experts to share their insights and experiences with a wider audience. Respondents stressed the importance of gaining on-site MCS experience and involving multiple players from different organisations. The thought conjoins with Feldmann et al. (2022) with the fact that MCS projects are more complex than conventional ones, hence the importance of experience and technical abilities of project parties in making timely decisions. Contractors without experience and technical ability can make costly mistakes leading to project delays and errors.

Overall, respondents recommended on-site learning through demonstrations or pilot modular construction projects, where professionals can

witness the construction process in action. Cross-company training was also suggested as effective for learning best practices in MCS, as proposed by R1. Collaboration between contractors and the government in joint ventures or partnerships for specific modular construction projects was another viable approach. As suggested by Ta et al. (2019), the government could establish skills development centres to facilitate knowledge transfer, resource sharing, continuous improvement, and networking opportunities among industry players.

Government plays a pivotal role in formulating strategies, as it holds the power for policy-making and decision-making in the country (Bello et al., 2023). Four respondents suggested that the government should establish modular guidelines. These guidelines could standardise and ensure consistency in the best modular practices related to design, manufacturing, transportation, and on-site assembly. Such standardisation would enhance quality and safety in modular projects, as per Gunasagaran et al. (2022). The guidelines should align with local building codes and other regulations specific to modular construction, simplifying project approval and permitting processes. To further streamline MCS processes, respondents suggested that the government should provide financial or non-financial incentives to construction stakeholders developing skills and practice of MCS. According to Teh & Zainal (2021), financial incentives may include tax deductions, grants, subsidies, rebates, and low-interest loans, while non-financial incentives could involve expediting project permit, recognition, awards, technical assistance, regulatory streamlining, facilitating networks and collaborations, and supporting R&D. Four respondents also recommended developing infrastructure as a strategic action for developing technical expertise for MCS in Malaysia. This would involve investing in and expanding the infrastructure that supports MCS, such as advancing manufacturing facilities, expanding factories, integrating technology, improving transportation networks, establishing logistics hubs, developing training centers, and providing temporary storage. In line with Ismail et al. (2022), infrastructure development is crucial for paving the way for widespread MCS knowledge and application, leading to more efficient, sustainable, and cost-effective construction practices.

Proposed Framework

A framework has been developed to provide a visual representation (Bolhassan et al., 2022) of the seven challenges associated with developing technical expertise in the adoption of Modular Construction Systems (MCS) in Malaysia, along with the ten strategies aimed at promoting the technical expertise related to MCS adoption in the country. It had been observed that the challenges and strategies are specifically directed towards the Government roles. The proposed framework is illustrated in Figure 1.

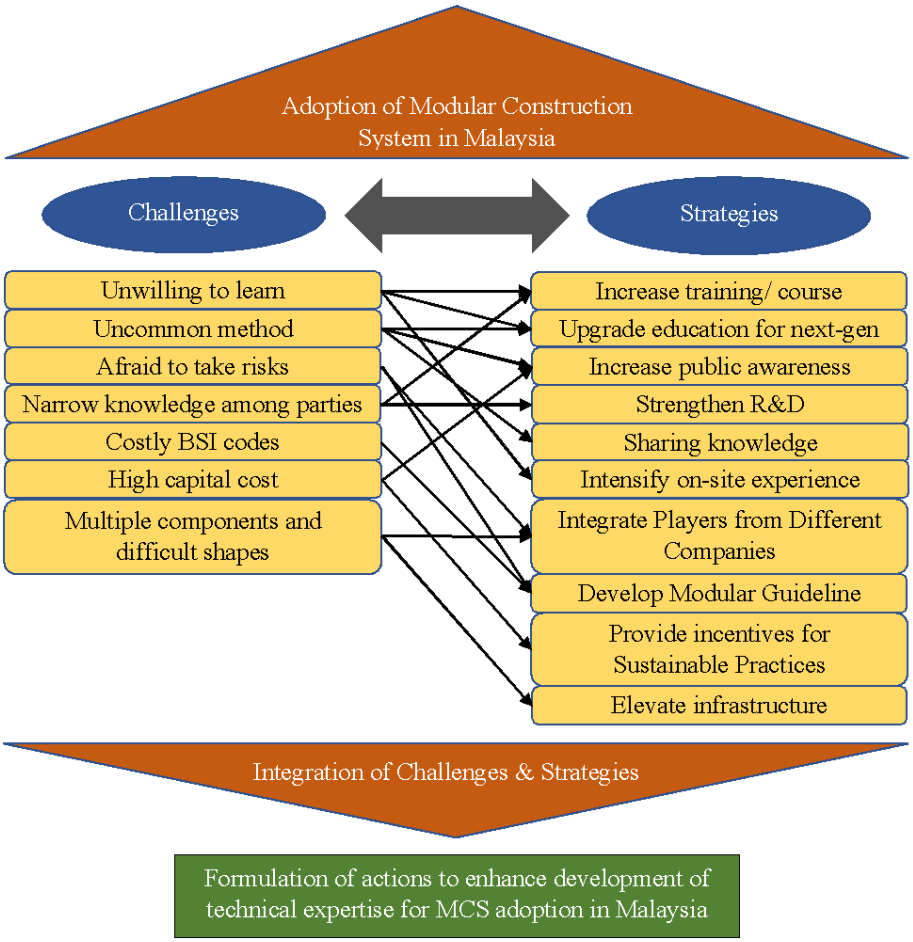

Figure 1: Preliminary framework to enhance the development of technical expertise for MCS

The primary goal of this framework is to facilitate a clear and organised understanding of the challenges and strategies in developing technical expertise of MCS adoption within the Malaysian context. The framework aims to assist four key stakeholders in taking effective actions to address the identified challenges and implement the suggested strategies. The challenges encompass various aspects while the strategies outlined are tailored to address these challenges. Recognizing the multifaceted nature of these challenges, the framework outlines how the government, through its regulatory and policy-making capacities, can actively contribute to addressing obstacles and promoting the integration of MCS. By delineating the roles of the government, the framework serves as a comprehensive guide, aligning strategies with governance

mechanisms to optimize the development of technical expertise within the construction sector.

CONCLUSION

The research has identified significant challenges in developing technical expertise for MCS: experience, knowledge and understanding, cost, and design. Among these, the study revealed that the most prominent challenge is the high capital cost, followed by reluctance to embrace MCS due to perceived investment and risk concerns.

The study also explored strategies to enhance MCS technical expertise in Malaysia. Respondents expressed that conducting training and courses is the most significant strategy, followed by the promotion of on-site experience among industry players, and knowledge sharing to raise awareness. Given the nascent stage of MCS in Malaysia, these strategies require collaboration from all stakeholders in the construction industry, with a particular emphasis on government involvement.

The data gathered were then developed into a preliminary framework that visually consolidates the findings and identifies that the Government holds the major responsibility in this effort. The framework seeks to pave the way for future researchers to navigate their studies more efficiently and achieve more impactful outcomes in the realm of MCS adoption in Malaysia. Despite taking views from contractors only, all parties may reap the benefit of the framework as it indicates the actions of all parties. Further research is encouraged on enhancing the findings by adding the data collection and analysis of views from multiple parties relevant to the development of MCS technical expertise.

ACKNOWLEDEGMENT

The authors would like to acknowledge the financial support from Universiti Teknologi Malaysia (UTM) for the funding under Universiti Teknologi Malaysia Encouragement Grant (UTMER) (Q.J130000.3852.31J49) and Universiti Teknologi Malaysia Fundamental Research (UTMFR) (Q.J130000.3852.22H71).

DISCLOSURE STATEMENT / ETHICAL STATEMENT

Following international publication policy and our ethical obligation as a researcher, we report that we have no conflict of interest.

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Received: 22nd Mar 2024. Accepted: 8th July 2024

