# Investigating the Implementation of Modern Methods of Construction in Saudi Arabia: A Roadmap for Future Development

Abdullah Alsehaimi[1]
Assistant Professor, Civil Engineering Department, College of Engineering, Taibah University, Madinah, Saudi Arabia, P.O.Box. 344
E-mail: aoasuhaimi@taibahu.edu.sa

***Abstract***

*Modern Methods of Construction (MMC) have been used to drive construction productivity, innovation, and sustainability in the building industry. However, the road to implementing MMC has been hindered. This paper attempts to establish a roadmap for the implementation of MMC in the Saudi construction sector through analyzing the current situation and determining the critical aspects involved. The research examines multiple aspects of MMC implementation in Saudi Arabia covering the type of MMCs available, the frequency of use of MMC, benefits, and barriers to MMC implementation. The investigation was executed through semi-structured questionnaire surveys involving 100 participants in the construction industry in Saudi Arabia. The study revealed that 66% of participants were aware of MMC, with flat slab construction being the most recognized method according to 86% of respondents. Furthermore, 98% believed MMC is underutilized in the Saudi Construction Industry. The potential benefits identified by the respondents include: reducing environmental harm according to 58% of the respondents, as well as improving project management, client satisfaction, and safety. However, concerns about training, supplier support, and rising costs were noted. The outcome of this investigation is expected to allow stakeholders to understand the key issues relating to MMC implementation and to develop suitable strategies for their wider implementation. The proposed roadmap is of a practical value which could support companies and practitioners on how to plan for MMC adoption.*

***Keywords:*** Modern Construction Methods (MMC), Saudi Construction Industry, Construction Productivity, Roadmap

## 1. INTRODUCTION

Modern Methods of Construction (MMC) encompass a range of innovative techniques aimed at improving construction productivity, efficiency, and quality. Also known as Off-site Construction Techniques (OCT), Off-site Fabrication (OSF), and Industrialized Building Systems (IBS), the terminology varies by region; for instance, "prefabrication" is commonly used in Asia (Kamar et al., 2014), while the UK favors "MMC," and the USA and Australia often use "off-site construction methods" (OSM) (Arif and Egbu, 2010; Smith and Timberlake, 2011; Švajlenka and Kozlovská, 2017). These methods have gained global recognition for their potential to address construction challenges (Wuni and Shen, 2020).

MMC involve manufacturing building components in controlled environments, leading to faster delivery, reduced waste, and enhanced sustainability. Lovell and Smith (2010) describe MMCs as technologies utilizing pre-manufactured structures or components. According to Burwood and Jess (2005), MMC are defined as construction methods that improve product management processes, yielding more and better products in less time using diverse materials (RNAO, 2005). The literature indicates that MMC offer significant advantages over traditional methods, including effective products, processes, and procedures that enhance construction preparation and execution, resulting in higher quality and reduced procurement times. However, successful implementation of MMC requires addressing associated challenges and barriers.

Despite their potential, the implementation of MMC technologies in the construction industry has been slow (Alsehaimi and Sanni-Anibire, 2024). In Saudi Arabia, MMC present a viable solution to housing

shortages and the demand for affordable housing. The government aims to provide approximately 300,000 housing units annually, with the Ministry of Investment (MISA) projecting a need for about 1.5 million new units by 2030 (Ministry of Housing, 2020). To manage the rapid growth of the real estate sector, the Ministry of Housing has initiated several proposals, including a building stimulus program designed to promote the adoption of MMC. This program emphasizes five key criteria: cost reduction, time reduction, increased quality and productivity, diversity, and local content, including job creation for Saudi citizens. Various MMCs, such as structural systems (concrete forms and light gauge steel) and modular systems, have been approved under this initiative.

Additionally, significant investments from the Ministry of Industry aim to revitalize the building technology sector and foster innovation in MMCs (Building Report, 2022). Beyond addressing housing needs, MMCs can support local initiatives aligned with international trends and commitments, including efforts to reduce carbon dioxide emissions. The successful implementation of MMCs contributes to various initiatives under Saudi Arabia's Vision 2030 and its commitments to the Paris Agreement.

Saudi Arabia has seen a surge in mega projects due to its ambitious Vision 2030 development plans. Within this context, MMCs are positioned as a solution to housing shortages, with government initiatives aimed at promoting their use to meet rising demands (Ministry of Housing, 2020). This research argues that, for such solution to be successfully implemented and introduced in the practice, it requires a roadmap and model which guide all stakeholders pursuing MMC adoption. Therefore, this study explores the status of MMC implementation in the Saudi Arabian construction industry, offering significant implications for stakeholders in the sector. The remainder of this manuscript presents an overview of MMCs, their advantages and barriers, followed by the methodology, results and findings, a discussion, a roadmap for future development, and conclusions.

## 2. LITERATURE RREVIEW

The following sections present a brief discussion on the advantages of MMC including its mitigation of construction delays, as much as 30-50% in time savings (MBI, 2010; Pan and Hon, 2018); improved quality and compliance by allowing controlled production environments (Gibb and Isack, 2003; Lane, 2006); cost savings due to reduced labor needs and site overheads (Gibb and Pendlebury, 2006; Gunawardena and Mendis, 2022); and lowering construction waste and carbon emissions (Monahan and Powell, 2011; Mao et al., 2013, Almutairi et al., 2024). Similarly, the literature discusses several barriers to MMC adoption including financial, operational, and knowledge-related hurdles (Bello et al. 2023).

Reviewing the recent literature on the topic revealed that the majority of related studies were mainly focusing on types, advantages and barriers. Undoubtedly, these efforts came up with valuable insights which contributed to advancements of MMC and applications. However, it is evident that there is a lack of research devoted to other issues like framework, models and roadmap to implement the MMC in practice. Hence, this study aims to cover gaps in current knowledge related to roadmaps and frameworks that can boost the adaption of MMC in construction practice.

### 2.1. Advantages of MMC

The literature encompasses several definitions of MMC in different parts of the world. “Modern methods of construction” (MMCs) has another terms used: OCT, Off-site Fabrication (OSF), Off-Site Production (OSP), pre-assembly, Off-site Manufacturing (OSM), and industrialised buildings system (IBS). The literature revealed various definitions of MMC in different parts of the world. The term prefabrication or industrialised building systems was found to be used in Asia (Kamar et al., 2014), UK favor the term MMC, off-site construction methods (OSM) is being used in USA and Australia (Arif and Egbu 2010; Smith and Timberlake 2011; Švajlenka and Kozlovská, 2017). In this Paper, the term MMC will be used to avoid confusion.

MMC can be perceived as a comprehensive term, used to describe various creative and new innovative improvement techniques, consisting of technologies whose structures and components are manufactured at plants (Lovell and Smith 2010, Meacham, 2022). Therefore, the main reason for MMC usage can be

perceived as minimizing waste, reducing time, improving quality thus improving performance (Švajlenka and Kozlovská, 2017, Wuni and Shen, 2020)
Various studies examined the advantages of MMC in different countries around the globe. It has been considered that the most significant value for MMC is reducing construction time (Gibb and Pendlebury, 2006; Arif et al., 2012). Based on the experiences with MMC techniques in various countries including UK, Australia, US, Singapore, Sweden, Saudi Arabia and Malaysia, the effective implementation of MMC leverages significant advantages such as speedy construction and enhanced productivity (Tam et al., 2007 ; Pan and Hon, 2018; Wuni and Shen, 2019; Lawson et. al.2012, Almutairi et al. 2017)
Another significant advantage for MMC is the production quality and productivity stability of the controlled industrialized environment compared to the uncertain conditions of a conventional construction site (Gibb and Isack, 2003 Mullens and Arif, 2006; Pan and Hon, 2018; Wuni and Shen, 2019, Almutairi et. al, 2024). Among the benefits of MMC, is the reduced need for skilled labour, which assists the construction process to move away from being a labour-oriented operation to a more process-oriented and assembly process (Gunawardena, and Mendis, 2022).

## 2.2. Barriers to MMC Implementation

Bello et al. (2023) identified nine significant barriers to modular construction systems in developing countries, including financial, operational, governmental, knowledge, technical, logistical, industry-specific, attitudinal, and aesthetic factors. All these elements are critical for effective implementation, highlighting the need for appropriate mitigating strategies.
Ali et al. (2023) focused on barriers in Egyptian residential buildings, pinpointing knowledge barriers (such as a lack of skills and experience), technical barriers (including insufficient technology and educational programs), and financial barriers (notably higher capital costs). Wuni and Shen (2020) proposed an integrated conceptual framework that outlined five key barrier categories: industry, knowledge, process, financial, and technical.
Williamson et al. (2019) examined the UK context, identifying barriers such as the need for standardized work systems, the necessity for MMC training for trades and management, and a shortage of skilled labor. Rahman et al. (2014) noted that while MMC presents numerous advantages, its uptake was low at the time due to high initial capital costs and traditional procurement methods creating contractual challenges. In China, Gan et al. (2018) identified major barriers to off-site construction, including a lack of knowledge and expertise, complex management, and the predominance of conventional project processes. These findings align with earlier studies highlighting issues such as high costs and insufficient governmental incentives as critical barriers (Mao et al., 2015; Zhang et al., 2014).

## 2.3. Types of MMC

MMC can be classified into two major categories: on-site MMC and off-site MMC. On-site MMC combines conventional materials with advanced manufacturing techniques, facilitating assembly directly at the construction location (Smith and Timberlake, 2011). Conversely, off-site MMC encompasses methods such as Precast Flat Panel systems, which are especially appropriate for uncomplicated development projects. Elements like precast concrete, prefab panels, and modules are produced in a factory and subsequently delivered to the site for assembly (Rahman, 2014). Off-site produced prefabricated building systems are generally categorised into three construction modes:
1- Modular (Volumetric) Construction involves the production of fully self-contained units in a factory, which are subsequently transported to the site for assembly into a complete structure.
2- Panelised Construction entails the fabrication of flat panel units at a factory, which are then brought to the site and assembled in order to build a full structure.
3- Hybrid Prefab Construction (Semi-Volumetric) integrates both panelized and modular methodologies (Gunawardena and Mendis, 2022).

## 2.4. Traditional Construction VS. MMC

MMCs are increasingly viewed as an ideal alternative to conventional construction methods, effectively addressing the challenges faced by the industry (Gan et al., 2018). MMC can be compared to traditional methods across several dimensions, including the cost of development (Goodier and Gibb, 2007), reduction in material waste (Tam et al., 2005; Jaillon et al., 2009), quality, and safety (Xue et al., 2017). MMC encompasses the fabrication and pre-installation assembly of building components, pieces, or modules at their designated sites (Goodier and Gibb, 2007), offering a more innovative methodology in contrast to traditional, labour-intensive construction techniques. Barrett and Weidmann (2007) believe that MMC has enhanced performance compared to conventional construction regarding carbon emissions, hence showcasing its sustainability potential.

# 3. RESEARCH METHODOLOGY

The adopted research methodology entails the use of a questionnaire survey. Questionnaire surveys imply that questions be formulated in a clear and straightforward manner (Jackson, 2009). The questionnaire consisted of six sections: respondents' background, professional background, knowledge of MMC, advantages of MMC, a comparison between MMC and traditional methods, success factors for MMC, and challenges that stand to MMC. Participants included construction experts from the Kingdom of Saudi Arabia. Multiple ways were implemented to disseminate the survey, involving hand-delivering physical copies and employing a web-based format for professionals nationwide. The analysis focused on the varied responses of the participants, utilising diverse charts that clearly demonstrate and elucidate the obtained data.
The survey included around 250 individuals engaged in engineering, particularly within construction professions such as contractors, project managers, and consultants, in Al Madinah Al Munawara. A total of 100 replies were obtained, representing a response rate of around 40%.

## 3.1. Demographics

The majority of respondents who supplied demographic data held a bachelor's degree (80%), a master's degree (10%), a doctorate (2%), and other professions (8%). The survey's sample encompasses a diverse array of age groups, with the majority of respondents (40%) aged 23–30, followed by those aged 30–38 (25%), 38–50 (23%), and 12% over 50 years. The distribution of professional experience is consistent throughout the other experience categories, with 72% having over 5 years of experience and 28% having less than 5 years. Among the 32% of those responding, architects included 20%, mechanical engineers 16%, electrical engineers 10%, and project managers 5%. The various degrees of competence examined in the study are further defined by the distribution of respondents' years of experience. Demographic details information about the participants is shown in Figure 1.

# 4. RESULTS AND FINDINGS

## 4.1. Knowledge of MMC, Current use and the Need for developing MMC

### 4.1.1 Knowledge of MMC

Figure 2 illustrates that 66% of participants had knowledge with MMC, signifying a robust knowledge foundation that could boost the quality of responses. The survey acts as an instructional tool for individuals unfamiliar with MMC, thereby enhancing interest in its implementation, which is a key objective of the research.

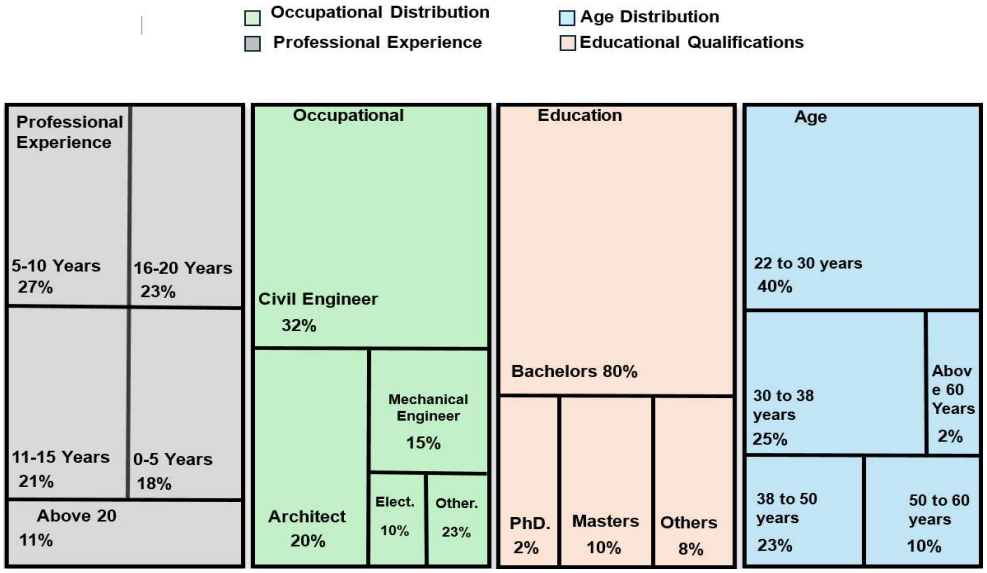


**Figure 1.** Details of the Demographics

### 4.1.2 Need for Developing MMC

The objective was to ascertain if participants believed that construction procedures necessitate additional advancement. The findings, presented in Fig. 2, demonstrate that 82% of participants believe enhancements are essential, whilst 18% answered "maybe." These findings highlight the essential requirement for contemporary construction techniques and indicate a robust match with the goals and objectives of our research. The prevailing opinion emphasises a shared acknowledgement of the prospective advantages and progress that may result from using novel construction methods.

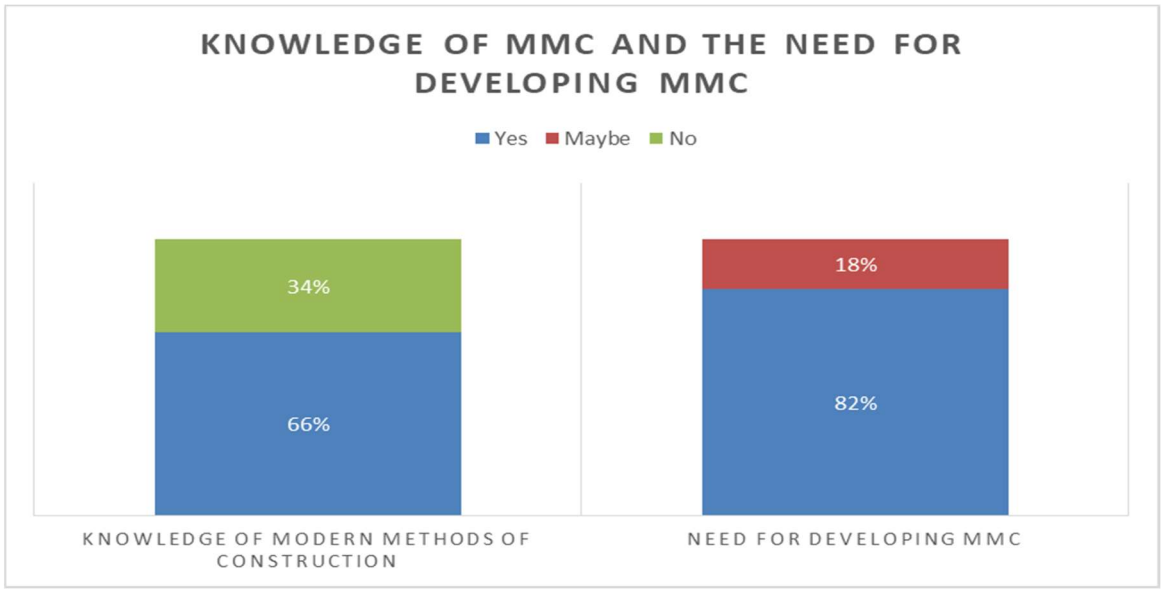


**Figure 2.** Respondents' knowledge of MMC and Respondents' opinion on the need for MMC development.

### 4.1.3 Knowledge of Various MMC Technologies

The bar chart in Fig. 3 reveals that flat slab construction is the most recognised approach, recognised by 86% of participants, followed by the precast flat panel system at 70%. Twin wall technology is the least acknowledged, with merely 34% of people being familiar with it. The results indicate a robust awareness of diverse MMC procedures among participants, suggesting a favourable outlook for the successful application of these methods in the sector.

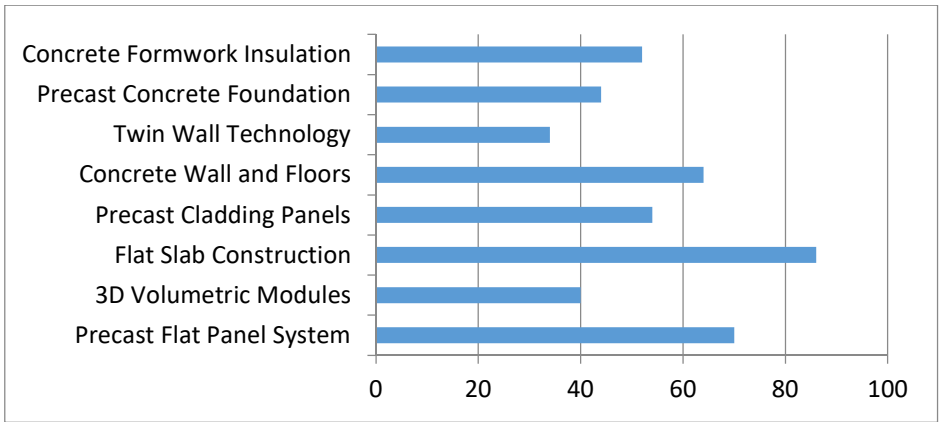


**Figure 3.** Respondents' knowledge of various MMC technologies.

#### 4.1.4 Current Usage of MMC in Construction

The results shown in Fig. 4 demonstrate that MMC is not as extensively utilised as expected, with over 98% of participants asserting that it has been used in less than half of the structures they encounter. These responses reveal substantial obstacles to the implementation of MMC, limiting its acceptance. The insights obtained from the current investigation will prompt participants to contemplate these constraints and provide valuable views and solutions that will assist in achieving its aims.

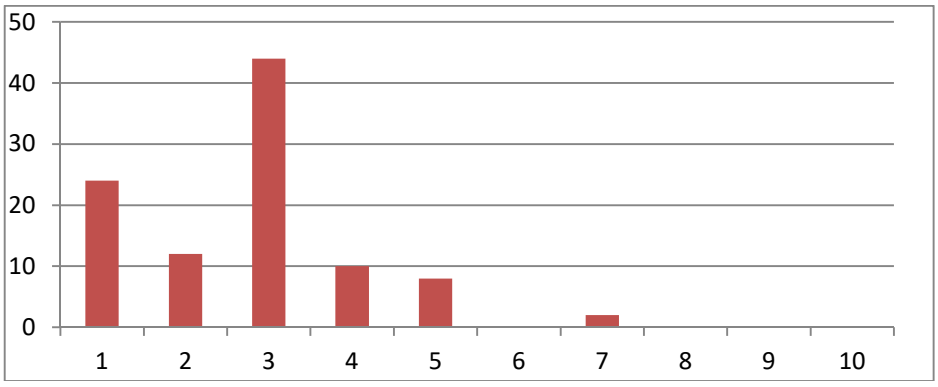


**Figure 4.** Current usage of MMC in construction.

## 4.2. Benefits of MMC

This type of questions intends to assess participants' perceptions of the advantages, benefits, and success determinants linked to MMC. Understanding these insights is essential, as they can highlight the beneficial elements of MMC that could encourage wider adoption and implementation throughout the sector.

**Positive Environmental Effect:** Figure 5 reveals that 68% of respondents believe that MMC will favourably impact environmental sustainability, whereas 30% remain sceptical however receptive to the prospect. Merely 2% anticipate that MMC will fail to mitigate adverse environmental effects. These data reflect a shared agreement among participants over the prospective environmental advantages of MMC. The growing recognition of the importance of sustainable practices may significantly stimulate the adoption of MMC. Encouraging participants to recognise the positive environmental impacts of MMC could boost enthusiasm and commitment for implementing these innovative techniques in the building industry.

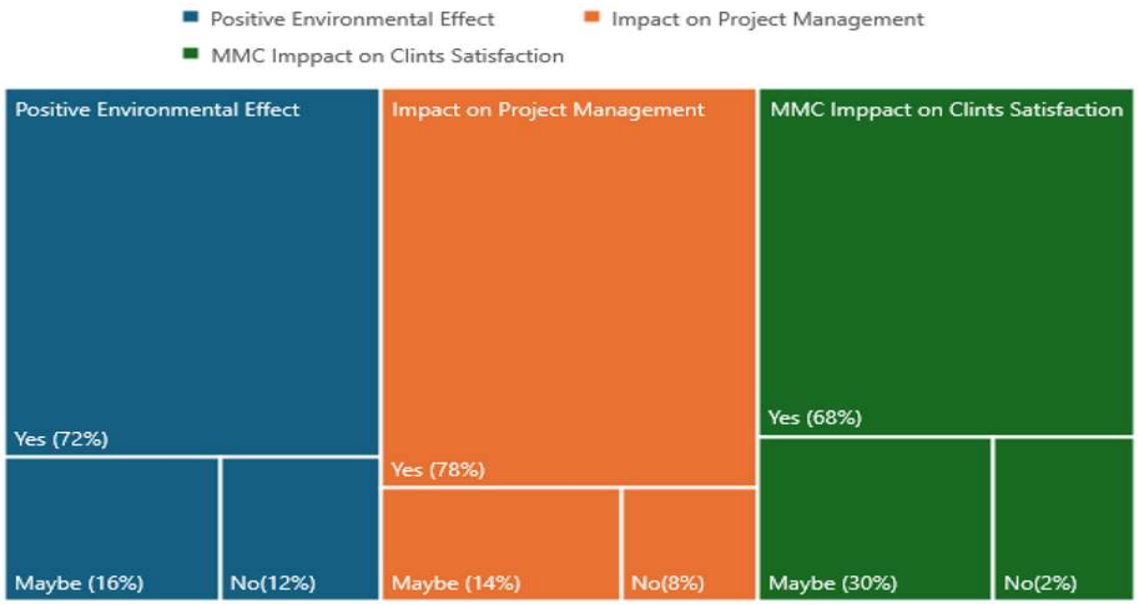


**Figure 5.** Respondents' knowledge of various MMC technologies.

**Impact on Project Management:** The results (Fig. 5) indicate that 78% of the respondents believe that MMC would improve project management and scope, but 14% remain uncertain, suggesting a possible beneficial impact. A minor fraction of individuals think that MMC will have no effect at all. These findings reflect a high level of confidence in MMC's capacity to improve project management processes. The prevailing perspective implies an opinion that the implementation of MMC can enhance management practices in construction, mitigating issues related to project execution and scope control. This insight strengthens the case for integrating MMC into the construction sector, as it clearly offers tangible benefits in project management.

**Impact on Clients' Satisfaction**: This question is designed to measure participants' perceptions regarding the efficacy of MMC towards improving client satisfaction and fulfilling requirements. Fig. 5 demonstrates that a large percentage of respondents, 72%, are assured that MMC can effectively meet client requirements and improve satisfaction. Simultaneously, 16% of respondents express uncertainty, while 12% do not believe that MMC is going to have such an effect. The findings emphasise a persistent confidence in MMC's capacity to meet customer expectations, confirming the absence of substantial trust constraints that might hinder its implementation. This favourable view motivates organisations to contemplate the adoption of MMC, suggesting that clients are likely to react positively to initiatives employing these methodologies.

## 4.3. Ranking the advantages of MMC Implementation

Participants were provided with several advantages that MMC can bring to the industry, allowing them to select the most relevant benefits. As shown in Fig. 6, the majority of the surveyed sample identified the reduction in labor force and time savings as the primary advantages of MMC, with over 75% of respondents highlighting these factors. Conversely, the least selected advantage was the increase in safety, with approximately 68% of participants recognizing it. This preference underscores the perception of MMC as a superior choice in terms of safety. Given that construction accidents result in significant loss of life and injuries each year, safety has become a critical concern within the industry. The overwhelming support for MMC as a safer alternative indicates a promising advantage that can facilitate its broader adoption. This perception of enhanced safety serves as a vital success factor for implementing MMC in construction projects. The results illustrate how MMC can significantly aid the construction industry, emphasizing these advantages as critical success factors for its implementation.

The strong support for time-saving, improving quality and reducing labor force indicates that these elements could drive broader acceptance and utilization of MMC in future projects. The results also indicated that approximately 58% of respondents believe MMC is more environmentally friendly and effective in reducing materials waste. These findings reinforce the notion that MMC can contribute to a cleaner environment and generate less waste compared to traditional construction practices, highlighting its potential as a sustainable solution for building industry.

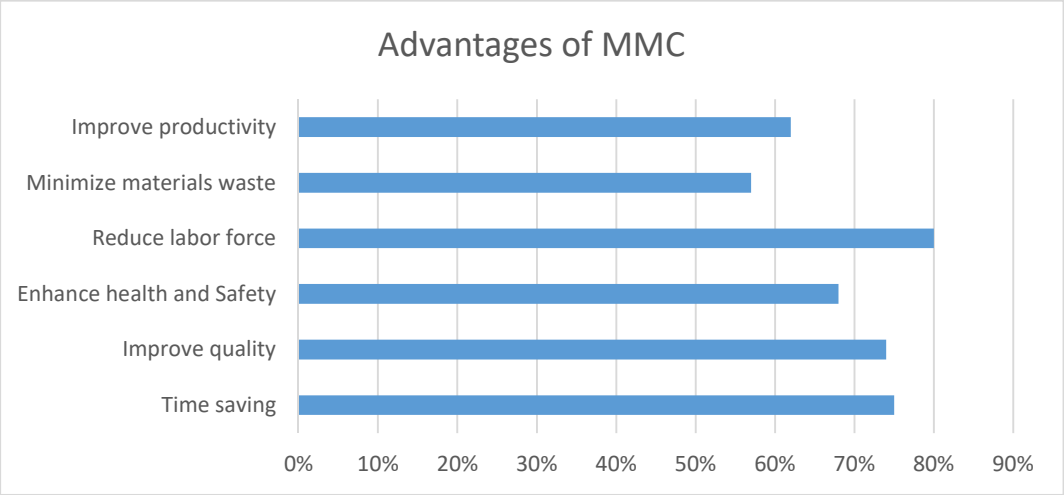


**Figure 6.** Ranking the advantages of MMC implementation in construction.

## 4.4. Success Factors for MMC Implementation

Fig. 7 shows that about 80% of the participants believe that MMC should be financially supported, emphasizing the significance of adequate experience and comprehensive training for successful implementation. More than 75% of participants indicated that existence of management support, governmental incentives are crucial factors for MMC success. The questions aimed at identifying barriers to the successful use of MMC have provided valuable insights into the challenges that may hinder its adoption. Analyzing these responses will guide us in determining key areas to focus on in order to overcome obstacles and enhance the implementation of MMC. This information is essential for facilitating a smoother transition to MMC in the construction field.

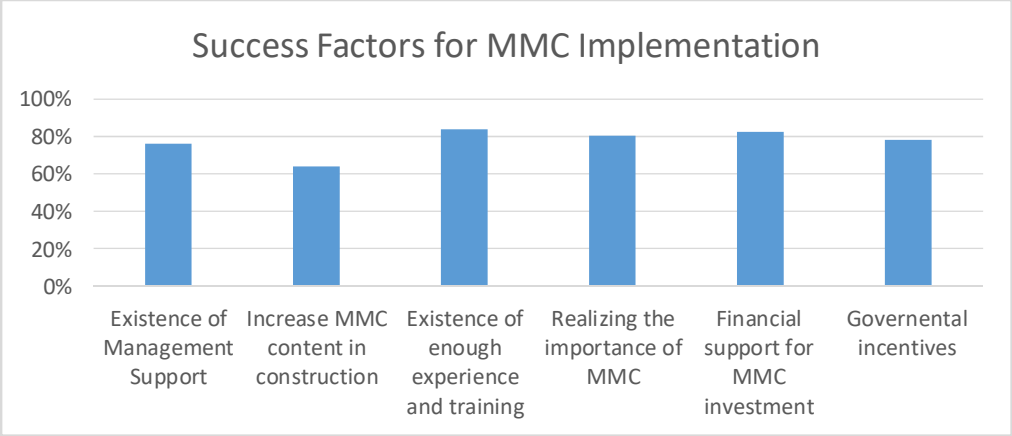


**Figure 7.** Ranking success factors for MMC implementation

## 4.5. Barriers to MMC Implementation

To identify the barriers to implementing MMC and the prerequisites for their efficient application in the building sector in Saudi Arabia, the surveyed professionals questioned about various proposed influencing hurdles. Fig. 8 illustrates that the input obtained from respondents can provide critical insights into the particular challenges, like elevated setup costs, insufficient skills and experience, and budgetary limitations, that impede the extensive use of MMC. The majority of participants recognised the scarcity of manufacturers and suppliers, together with escalating capital expenditures, as the principal obstacles confronting Modern Methods of Construction (MMC), with over 80% concurring on these matters (Figure 8). Conversely, apprehensions over the lack of rules and standards were deemed the least substantial obstacle, indicating that participants perceive the possibility of developing such regulations. Comprehending these obstacles is essential for assessing their potential to hinder the adoption of MMC in the construction sector. The insights derived from this inquiry will assist us in pinpointing critical areas of concentration, facilitating the formulation of plans to surmount such challenges.

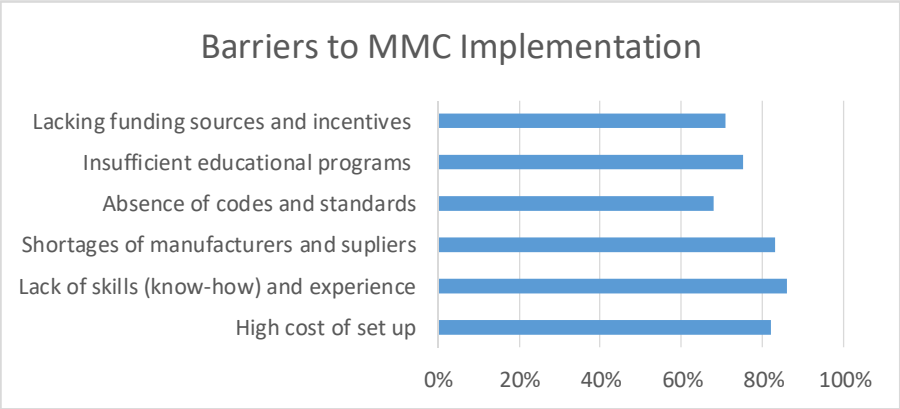


**Figure 8.** Barriers to MMC Implementation.

## 4.6. Recommendations for Promoting MMC Implementation

The participants requested to identify effective techniques for enhancing the adoption of MMC. The results shown in Fig. 9 were closely aligned, with over 80% of respondents reporting that support from the top management and the provision of training programs will be effective. The preferred strategy among the options was the provision of essential equipment and materials. These insights are crucial for formulating recommendations that would enhance the effective use of MMC in the Saudi buildings industry.

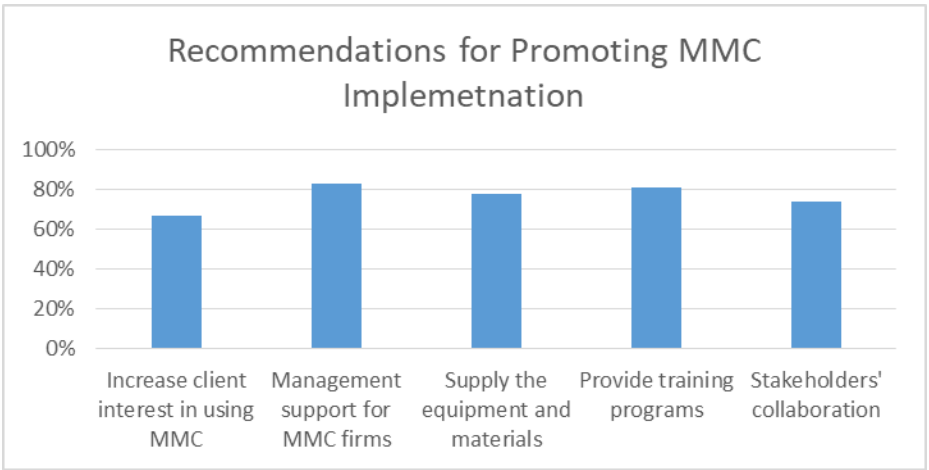


**Figure 9.** Recommendations for MMC Implementation.

## 5. SUMMARY AND DISCUSSION

This research investigated the implementation of MMC in Saudi Arabia. The results revealed that over 75% of respondents believed that MMC can significantly lower construction time, making it an attractive option for contractors and clients seeking efficiency. The advanced techniques associated with MMC were also recognized for their potential to enhance quality, with 73% of respondents noting that MMC requires different skills and expertise compared to traditional methods. Likewise, MMC was seen as beneficial for project management and scope, with 78% of participants agreeing it could improve these aspects, thus fostering greater satisfaction within organizations. Approximately 60% of participants acknowledged that MMC contributes to a cleaner environment by reducing waste, aligning with global trends toward sustainable construction practices.

The study also highlighted the potential barriers to MMC implementation in Saudi Arabia. Many participants indicated that the lack of funding sources and incentives poses a barrier to adopting MMC. Governmental incentives and innovative financing models is crucial for overcoming this inertia. The need for specialized skills and equipment was identified as a significant barrier. The study suggests providing training programs and hiring experienced professionals to build capacity within the industry. Participants noted that decreasing support from suppliers could hinder MMC adoption. Improved communication and coordination among stakeholders are essential to ensure timely delivery and standardization of components. The capital-intensive nature of MMC, with high start-up costs for manufacturing facilities and fixed overheads, presents challenges. However, the long-term benefits in quality and efficiency can outweigh these initial investments. Lastly, the study revealed a general acceptance of MMC among construction professionals, with 82% of participants believing that MMC should be utilized in future projects. This indicates a readiness to explore MMC as a viable alternative to traditional construction methods.

## 6. FUTURE DEVELOPMENT ROADMAP

This study proposes a framework for the efficient implementation of MMC in the Saudi construction sector. Fig.10 illustrates a development path for MMC deployment, originally derived from literature and subsequently refined through participant interaction in the questionnaire. This roadmap is remarkable in its explicit emphasis on the advantages, success variables, and obstacles related to the adoption of MMC in the Saudi construction industry.

| Benefits | Barriers | Recommendations |
|---|---|---|
| **Speedy Construction**<br>• Reduced construction time<br>• Enhanced labor productivity<br>• Improve job site efficiency | **Organizational and Process**<br>• Lack of manufacturers and suppliers<br>• Lack of codes and standards<br>• Policies and regulations | • Management support for MMC firms<br>• Building codes<br>• Streamlined methodology<br>• Plan for MMC introduction |
| **Cost Saving**<br>• Reduce running and maintenance costs,<br>• Decrease preliminaries<br>• Minimize site overheads, | **Industry barriers**<br>• Traditional Standardized system of work<br>• Procurement methods and Materials supply chain<br>• High cost of setting up a factory | • Right policies should be in place<br>• Stakeholders' collaboration<br>• Integrate Lean with MMC<br>• Raise the awareness thus increase client interest in using MMC |
| **Reduced need for labor**<br>• Decreased labor force<br>• Reduced need for skilled labor<br>• Process-oriented manufacturing | **Knowledge Barriers**<br>• Lack of skills and experience<br>• Insufficient educational programs | • Increase MMC content in construction education at all levels<br>• Provide training programs |
| **Environmental and Sustainable Benefits**<br>• Reduce CO2 productions<br>• Improve energy efficiency<br>• Reduce waste of building materials | **Technical Barriers**<br>• Limited Infrastructure<br>• Manufacturing capacity<br>• Technical skills (know- how) | • Support integrated training models<br>• Invest in Research and development<br>• Utilize emerging construction technologies (i.e. IR4.0) |
| **Safety, Quality and Compliance**<br>• Controlled factory environment<br>• Quality control<br>• Improving health and safety | **Financial Barriers**<br>High initial capital cost<br>Lacking funding sources and incentives<br>Absence of Innovative Financing Models | • Financial support for MMC investment<br>• Governmental incentives<br>• Collaboration with funders |

**Figure 10.** Roadmap for MMC Future Development.

## 7. CONCLUSION

This study provided valuable insights into the introduction and advantages of MMC within the construction industry. It highlights the potential for MMC to enhance the quality of construction projects while addressing the challenges commonly associated with traditional methods. By leveraging MMC, engineers can optimize their workflows, resolve issues more efficiently, and complete projects within tighter timelines. The following recommendations can be put forward to facilitate the effective implementation of MMC in Saudi Arabia's construction sector:

1- Construction companies should focus on the direct benefits of MMC and secure the necessary resources for initial investments.
2- The distinct implementation techniques of MMC necessitate specialized skills and expertise. Therefore, construction firms need to establish training programs for their workforce, including engineers and managers.
3- Encouraging client interest in MMC is vital, particularly for complex designs that MMC can simplify.
4- Raising awareness and understanding of MMC should begin in educational institutions. By integrating MMC principles into construction curricula at all levels, future professionals will be better prepared to implement these methods in their careers.

It has been stressed that the significant potential of MMC to enhance the efficiency and effectiveness of construction processes in Saudi Arabia. The positive perception of MMC among survey participants indicates a readiness to embrace these modern methods, and the research has identified barriers that can be overcome through targeted actions. The roadmap promises substantial benefits to all stakeholders.

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