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Barriers Affecting the Implementation of Modern Methods of Construction (MMC) in Oman

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ABSTRACT

Traditional construction practices have always faced issues such as cost overruns, construction delays, and construction waste. Oman is no exception to these challenges because it primarily relies on traditional construction methods. To overcome these challenges and increase project efficiency, adopting Modern Methods of Construction (MMC) in Oman is crucial. However, the successful implementation of MMC is hindered by various barriers, which need to be addressed.

This research project aims to identify the barriers that impede the implementation of MMC in Oman. Data was collected through surveys and in-depth interviews with MMC stakeholders in Oman. The survey questionnaire presented 18 potential barriers, and respondents were encouraged to distribute the survey to their contactors who are familiar with MMC. About 400 surveys were distributed to a selected sample of civil engineers, architects, academic institutions, clients, consultants, contractors, and other relevant professionals. Additionally, four MMC experts in Oman were interviewed for their insights.

The findings reveal that the most significant barriers to MMC implementation in Oman are high initial costs, supply chain disruptions, an emerging MMC market, inadequate government support, and transportation challenges. These barriers hinder the adoption of MMC and impede the realization of its potential benefits.

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Introduction

The construction industry in Oman faces numerous challenges due to its reliance on traditional construction methods, including cost overruns, delays, and waste [1]. Many countries have adopted Modern Methods of Construction (MMC) to address these issues and enhance project efficiency. However, implementing MMC in Oman requires overcoming specific barriers [2]. Successful implementation of MMC in Oman is expected to reduce these challenges and significantly improve overall efficiency [3]. This research aims to identify barriers to MMC implementation in Oman, evaluate available MMCs in the country, understand causes affecting MMC implementation globally, analyze related research on MMC in Oman, and interview MMC stakeholders in Oman. The research outcomes are expected to assist the Omani government and construction companies in developing strategies to overcome identified barriers in the future.

Definition of MMC

The construction industry in Oman is considered one of the main contributors to growth in the Gross Domestic Product (GDP); thus, improving this sector is crucial [4]. However, it is evident that most projects in Oman are constructed by using the traditional brick and block methods, and using these methods has many problematic issues and challenges that could negatively affect the efficiency and productivity of building projects, such as cost overruns, construction delays, construction wastes, vast use of materials and energy, site accidents, questionable quality, environmental pollution, etc [5]. Despite the fact that much research has been done for a long time to study these issues, they still need to be treated or resolved. Modern Methods of Construction (MMCs) are an option to avoid and resolve these issues [6]. There is no clear definition of MMC; most researchers define it as prefabrication and offsite construction products or processes, and definitions of MMC have been different over the years. Describes MMC as a construction method that makes components offsite and moves them to the site for assembly or parts made and assembled offsite [7]. Another definition is MMC, which is a method that provides an efficient product management process to deliver more projects of better quality in less time [8]. However, in 2018, MMC has been defined as a broad term that involves a range of offsite and onsite manufacturing and techniques that afford alternatives to the conventional methods; it ranges from whole buildings being developed from offsite built volumetric modules to modern techniques for laying Cast-in-situ concrete [9]. It can also be defined as a term that is used to describe many different construction methods in which building projects are developed using non- traditional methods [2].

Types of MMC

MMC can be classified into two categories: Offsite Manufacture (OSM) and Non-Off-Site Manufacture [10]. The offsite manufacturer includes methods carried out away from project sites, such as panel building systems, volumetric or modular construction, hybrid or Semi-volumetric, and sub-assemblies and components construction. Another category is non-offsite manufacturing, which includes building methods and techniques that cannot be classified as offsite construction. Examples are Tunnel Form and Thin-Joint Masonry. (Table 1) presents a brief explanation of some types of MMC.

Table 1: Types of MMC with a Brief Description

Types of MMC	Brief Explanation
Panel building systems	These include floors, roofs, and walls in the way of pre-engineered panels that are created onsite to form the structure of elements that then need different finishing levels.
Volumetric/ Modular construction	Units or modules that are built in the factory are used to develop the structure of the building.
Hybrid/Semi-Volumetric	This method is used when both panel building systems and modular construction are together used to construct buildings.
Sub-assemblies and components	Suppose any part of the building is produced in a factory, like pre-casted concrete, floor, roof cassettes, etc., and traditional methods construct the rest. In that case, it is called Sub- assemblies and components construction.
Tunnel Form	This is an onsite innovation. It is a formwork process that simplifies the casting of slabs and walls in one operation. It is commonly used in repetitive cellular projects like student accommodations, apartment blocks, and hotels.
Thin-Joint Masonry	This is also an onsite innovation. It is a masonry construction method that replaces normal mortar joints with thinner mortar joints by utilizing specific adhesive mortar.

History of MMC

The idea of MMC had begun at a time of high demands for house buildings caused by population growth and wars. After the Second World War and in different periods, MMCs have been used in many countries that had urgent housing crises, such as Sweden, Germany, Japan, The United Kingdom, and the Netherlands [11]. Japan and the United Kingdom had a building crisis with more than 4.2 million and 200 thousand building units, respectively, to support their people who lost their homes because of the war. From 1965 to 1975, Sweden was required to supply 1 million housing units, and in 1996, around 800 thousand housing units were needed in Malaysia to accommodate their new population growth [11]. Governments have developed MMC programs to meet rising demands alongside conventional methods. MMC depended on prefabricated parts and manufacturing of the construction in offsite factories to build the building units in a shorter time, at better quality, and a lower cost. In the United Kingdom, in 1944, the emergency factory-made program (EFM) was deployed and developed, which delivered around 153 thousand temporary prefabricated houses and ended because of poor quality [12]. Types of MMC have been established in response to demand for building due to wars, population growth, lifestyle change, etc.

Consequently, many different types of MMC have been established over the years and contain many innovations, such as offsite production, modular building, industrialized building, prefabrication, offsite manufacturing, preassembly, and also many onsite methods [13]. The advantages of MMC have been noticed in many developed countries, but the uptake of them still needs to be higher. Many other developed countries, like Germany, Scandinavia, Japan, the USA, the UK, etc., have started using MMC on a broader scale [14]. In Oman, a few MMCs were approved by the government, such as Light Gate Steel (LGS), Precast Concrete, Rapid Wall, and Insulated Concrete Forms (ICF). MMCs have been given different names, such as offsite construction in the UK, China, and Australia and industrial building systems in Malaysia, Japan, and Sweden. They were prefabricated in Hong Kong and Singapore, and the Modern Method of Construction MMC in the United States [15]. In this research, MMC is used as it is the most common name in many countries.

Literature Review

This part of the literature review discusses various studies on MMC, including its benefits, common barriers, and examples.

Benefits of MMC

The benefits of MMC have yet to be discovered since research on MMC is still ongoing [16]. However, what has been found till now is that MMC has many benefits and advantages compared to traditional construction methods. For instance, time reduction, Occupational accidents reduction, quality improvement in construction, cost reduction, profitability improvement, waste reduction, overcoming shortages in the availability of skilled labor for the traditional method, water and electricity saving during manufacturing, mitigating environmental impact, significant reduction of the impact on the community surrounding the construction site, and elimination of weather effects on construction of buildings [17].

Common Barriers to MMC

The literature review indicates many barriers to MMCs, and they differ from country to country. However, in general, the most common barriers are cost-related issues, lack of skills and experiences, motivation and culture issues, tools and standards issues, a market of MMCs, industry-related issues, project-related issues, and interface and flexibility. They are explained below.

Cost-Related Issues

Most MMCs depend on offsite manufacturing; thus, they require factories to produce modules and components, and these factories need high start-up costs to set up a prefabrication yard and suitable machinery for the production of the modules and components. They also have to buy all relevant materials at the beginning of the project, which causes high initial costs. In addition, most factory overhead costs are foxed, like labor, regardless of production. Moreover, if precast elements are in small quantities, the building cost per unit becomes high. These lead to the higher initial costs of MMCs and also higher overall costs than conventional methods, which might cause difficulties in finding finance to implement MMCs [18].

Skills and Experience
MMCs need highly skilled technicians for both manufacturing modules and elements in factories and assembly on site, and several of the various types of MMCs are innovations. Moreover, many people in the construction industry need more experience with MMCs. In addition, a few projects have been constructed using MMC; thus, people are not encouraged to learn it. Students also in colleges are less exposed to learning MMC since it is not yet commonly used in the construction industry [19].

Motivation and Culture
Many people do not trust MMCs in terms of quality and performance because of previous high-profile failures. Most of the modules and components of MMCs are very lightweight, leading to the idea that they are less durable, of bad quality, and may demand frequent refurbishing. Many people and companies have a certain mindset and want to avoid trying new methods. This causes companies to be reluctant to change and use MMCs [19].

Tools and Standards
Most of the various MMC methods are relatively new, and others have recently become applicable alternatives to conventional methods. Thus, there needs to be more design standardization, and the relevant quality assessment accreditations and tools still need to be established. Because of that, fewer standards and codes are available for MMCs, and the regulatory authorities still need to include many of them in planning regulations [6].

Market of MMCs
Because traditional construction is dominant, suppliers want people or companies to refrain from using MMC because they fear that profits will decrease. Therefore, many suppliers of traditional construction try to protect the market from MMC through different procedures, such as selling supplies at a lower cost than MMC could offer [6].

Industry Related Issues
MMC requires effective coordination and frequent communication among involved parties throughout a project to confirm that deliveries arrive on time. However, the construction industry's fragmented nature restricts such coordination and communication, which makes it harder to regulate designs for MMC. This means that parts from various suppliers might not fit together, causing a more significant number of defects and lower quality structure [6].

Design Issues
MMC must have an early design to allow early manufacturing of required modules and components. This makes MMC unsuitable and inflexible for late design changes. Furthermore, once production begins, changes in design affect how these various components will fit together. Moreover, MMC follows standardized designs that are different from traditional construction; thus, problematic issues accrue when combining traditional methods with MMC [6].

Project-Specific Issues
Since modules and components for MMC tend to be large, some sites with limited space might not be appropriate for MMC. Furthermore, MMC is not suited to small projects due to the expensive transportation of the significant elements and modules to the site. Moreover, some projects might be far away from the factories of MMC; consequently, the heavy and oversized loads have to be transported a long distance, causing expansive costs of transportation [18].

Examples of MMC
Table 2: Examples of MMC with a Brief Explanation

List of MMC	Description
Insulated Concrete Forms (ICF)	This method of construction involves placing two high-density foam layers with an opening between them that is filled with concrete to build a wall.
Structural Light Gauge Steel (SLGS)	Cold-formed steel panels are manufactured at the factory and transported to the site for assembly.
Modular Light Gauge Steel (MLGS)	Steel columns are set with steel beams to produce a reliable construction skeleton.
Tunnel Formwork (TF)	A formwork process that simplifies the casting of slabs and walls in one operation. It is commonly used in repetitive cellular Projects like student accommodations, apartment blocks, and hotels.
3D-Printed construction	This method is used to produce elements or entire buildings by using a 3D printer that prints concrete or another materials layer-by-layer.

Methodology
The research used both primary and secondary methods to gather data, which allowed the data gathered to complete each other. Literature reviews, as secondary data, were used to become more familiar with the MMC, including various books, journals, online articles, and research. In primary data, both a survey and an interview were used to collect the necessary data. Besides, this research used a mixed approach; both quantitative and qualitative methods were used to reach the aim and objectives of this research precisely.

Design Methodology
The first step after reading the literature review was to collect the necessary data through the survey, which was completed using the literature review. The survey consists of four sections. The first section includes questions about the respondents' characteristics, i.e., academic qualifications, work sector, and experience. The second section comprises yes/no questions about awareness of MMC and the benefits of MMC in terms of cost, time, and quality. The third section contains eighteen barriers of MMC, and the barriers are:

1. Cost-related Issues.
2. Culture and Motivation.
3. Low market demand.
4. Lack of professionals in Oman.
5. Resistance to change.
6. Complicated management.
7. Not suitable for small projects.
8. Design change difficulty during construction.

9. Tools and Standards.
10. Dominance of traditional construction method.
11. There is currently no standardization for MMC components in the market.
12. Longer pre-construction stage.
13. More capable consultants and designers.
14. Shortage of capable contractors on prefabrication activities.
15. Shortage of vendors that supply prefabricated parts.
16. Less tolerance between factory components and onsite assembly.
17. Expensive long-distance transportation for large and heavy loads.
18. Unsustainable, so requires frequent refurbishing.

The last section contains one question about if any other barriers should have been mentioned in the survey. The survey was formed in Google format and distributed through email and WhatsApp, providing the survey link to get online responses. The actual distribution number cannot be proved since potential respondents were asked to distribute the survey to their contacts who are familiar with MMC. However, around 400 surveys were sent to carefully selected segments of civil engineers, architects, clients, academic institutions, contractors, consultants, and others. IBM SPSS Statistics software was used to analyze the data, and the mean score of individual barriers was compared and ranked among the participants according to Academic qualification, work sector, position in the construction industry, years of experience, and organization type. The Normality Test was used to check whether the survey was normally distributed and to decide whether to use parametric or non-parametric statistics. Then, a reliability test was used to check if the data gathered were reliable or not reliable. Finally, factor analysis was used to analyze the factors.

After that, four in-depth interviews were held with MMC experts in Oman. For example, co- founder of eco houses, engineer of Light Gauge Steel (LGS), engineer of 3D printed construction, and project manager of Rapid Wall. In the interviews, the results of the survey were discussed. Moreover, many other questions were asked. For instance, what type of MMC do they implement, what advantages and disadvantages of this type, why this type and different types of MMC are not common in Oman, and what steps should the government take to promote/encourage the adoption of MMC in Oman, barriers that affect the implementation of MMC in Oman.

Results and Discussion

This section presents the findings and analysis of the research conducted to fulfill the study's purpose and objectives. The survey and interview results were both presented and discussed.

Survey Results

There were 179 responses collected from the survey, 87 of them from Civil Engineering, 60 responses from Quantity Surveyors, 12 responses from Mechanical or Electrical Engineers, 9 of them from architects, 4 responses from clients, and 7 of them from other positions. Besides, the majority of participants have (1-5) years of experience, 33 of them have (6-10) years of experience, 19 of them have (11-15) years of experience, 11 of them have (16-20) years of experience, and 20 of them have more than 20 years of experience. (Table 3) describes the specialists of the survey responses based on SPSS analysis.

Table 3: Positions of the Survey Responses

Ranks			
	the position	N	Mean Rank
Mean18_2	1	87	72.70
	2	60	114.93
	3	12	65.83
	4	9	92.94
	5	7	79.07
	Total	179	

Respondents indicated their importance on a scale from 1 to 5 (varying from Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree) on 18 barriers of MMC in Oman. Based on (IBM Corporation, 2021), results showed that the survey is generally distributed because both the Kolmogorov-Smirnova test and Shapiro-Wilk test are 0.13, which is above the 0.05 level of significance, as explained in Table 4 [20].

Table 4: Result of the Normality Test

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Mean18_2	.076	179	.013	.980	179	.013
a. Lilliefors Significance Correction						

In the reliability test, and based on (IBM Corporation, 2021), Cronbach's alpha must be above 0.70 to be considered reliable [20]. In the survey, results showed, as evident in Table 5, that responses are reliable because Cronbach's Alpha is 0.907.

Table 5: Result of the Reliability Test

Reliability Statistics	
Cronbach's Alpha	N of Items
.907	22

After that, KMO and Bartlett's Test was conducted to determine whether or not factor analysis could be executed. KMO and Bartlett's Test are used to determine how the factors explain each other and to check the strength of the partial correlation between them. KMO must be above 0.5 to be acceptable, and closer to one is considered excellent [20]. The survey indicated that KMO and Bartlett's is (0.888), as clarified in Table 6, which is good enough for factor analysis to commence.

Table 6: Result of KMO and Bartlett's Test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.888
Bartlett's Test of Sphericity	Approx. Chi-Square	1342.053
	df	153
	Sig.	<.001

Moreover, of the 18 barriers, the top three are the lack of MMC professionals in Oman, the expense of long-distance transportation, and the cost-related issues.

Discussion

The barriers indicated in the survey were discussed in the interviews with some of the MMC stakeholders in Oman. The survey outcomes presented in this research evaluated 18 barriers that might be a reason that affect the implementation of MMC in Oman. The top three barriers from the survey are the need for MMC professionals in Oman, Expensive long- distance transportation, and Cost-related Issues. After discussing these barriers in the interviews, it was found that these barriers are realistic; however, other barriers can also be more critical than what has been found in the survey. For example, low market demand for MMC and Lack of Government Support. All in all, after reading the literature review, analyzing the survey, and conducting four in-depth interviews, it can be said that the most critical barriers to implementing MMCs in Oman are the following:

Supply Chain Issues

Results show that common interior design elements and all essential raw materials are available in Oman. However, the country needs more expert engineers, experienced architects, and skilled technicians, which is considered to be a critical barrier to implementing MMC.

Low Market Demand for MMC

The dominance of traditional construction methods in Oman is one of the critical barriers affecting the implementation of MMC, in addition to low market demand for MMC. Moreover, big construction companies in Oman are using traditional methods. Thus, it is difficult for MMC to be implemented since they believe that successfully implementing MMC in Oman might negatively affect their companies.

High Capital Cost

Most MMCs are offsite construction, requiring factories with high initial and operating costs, which is also a critical barrier to implementing MMCs in Oman.

Lack of Government Support

Lack of government support in terms of giving permits from municipalities and providing codes and standards for MMC are also the main barriers to implementing MMC in Oman.

Transportation Issues

The size and load restrictions on transportation are also critical barriers affecting the implementation of MMC in Oman. These restrictions limit the number of manufactured heavy elements per transport, driving the cost of a housing unit upward through increased transportation costs.

Conclusion

The adoption of MMC in Oman needs to be deeper despite its great benefits. This has led to the present research on identifying barriers to MMC in Oman. Data was collected through a survey and interviews. SPSS software was used to analyze the survey data. Normality test, reliability test, and factor analysis were conducted. The result of the normality test was 0.013 in both Kolmogorov-Smirnov and Shapiro-Wilk, indicating that the survey data is usually distributed. The result of the reliability test was 0.907, which is very good since it is above 0.7. In factor analysis, the overall results indicated that, of the 18 barriers, the top three were the lack of MMC professionals in Oman, expensive long-distance transportation, and cost-related issues. The results of the survey were discussed in the interview, and the outcome of this research was that the critical barriers to implementing MMC in Oman are supply chain issues, low market demand for MMC, high capital costs, lack of government support, and transportation issues. Finally, this research will help the government or private sector in Oman study these identified barriers and the required strategies to overcome them and successfully implement MMCs in Oman on a broader scale.

Government intervention is crucial for the implementation of Modern Methods of Construction (MMC) in Oman. Currently, companies need more incentive to invest in modern construction methods or to use MMC as their preferred construction method. By implementing MMC in Oman, the government can benefit from it, especially in the face of natural disasters such as Cyclone Gonu in 2007, Cyclone Mekunu in 2018, and Cyclone Shaheen in 2021. MMC has proven to expedite large-scale projects at a lower cost, enabling the government to aid those affected by disasters efficiently. However, there are still concerns to address, including the durability and longevity of MMC solutions, thermal mass issues, the potential for systemic failure, and acoustics [14].

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