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A Framework to Adopt Modern Methods of Construction in Social Housing Projects in Egypt

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Abstract: Egypt, one of the largest countries in Africa and the Middle East and North Africa (MENA) region, is facing a severe shortage of low-income housing. Despite implementing several housing policies, the deficit continued to grow, especially with the continuous increase in population and other economic and socio-cultural challenges. The rationale behind this research is to propose MMC as a solution to address the shortage of low-income housing as well as the challenges that the Egyptian construction sector is currently facing. A convergent parallel mixed method approach was adopted for data collection and analysis by merging qualitative and quantitative data to provide comprehensive results. From the results, a framework to adopt MMC in social housing projects was established, consisting of seven main pillars that cover the influencing factors on its implementation. The framework was divided into four phases to ensure successful implementation, including the role of the involved stakeholders during each stage.

Keywords: offsite construction; prefabrication; housing; modern methods of construction; social housing

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1. Introduction

Providing adequate housing to the least-advantaged households in developing countries is always challenging. Numerous households cannot meet the cost of decent housing with acceptable standards supplied by the private sector, leaving the burden of supplying affordable housing to the public sector. Without social and affordable housing through the public sector, a vast proportion of the poorer society will fail to obtain decent housing. Insufficient funding, continuous increase in population, construction delays, poor quality, and low technological uptake in construction are all contributing factors to this challenge. As a result, governments have continuously developed housing programmes and policies to deliver mass housing to shrink the gap between supply and demand. These programmes include adopting new construction methods to speed up housing delivery, introducing funding initiatives and housing policies, and partnering with the private sector to increase the number of affordable housing units.

2. Housing in Egypt

In Egypt, the housing shortage has long been recognised, with the supply of affordable units failing to meet the increasing demand. Egypt is one of the largest countries in the Middle East and Africa in terms of population and size of the economy. The population in Egypt has exceeded 100 million, with an average increase rate of 2% [1]. The total area of Egypt is one million km^2, with only 5% being populated around the Nile Valley and delta, while the remaining area is an unoccupied desert. Although the current inhabited population density of the country is 1473/km^2, the inhabited population density in Cairo, the capital, reached 52,237.4/km^2 in 2020 to be one of the most populous regions in the Middle East and Africa [2]. This sharp increase in the population density of Cairo is driven by migration from rural to urban, accompanied by overcrowding and slum dwellings.

The government has solely taken responsibility for reducing the housing shortage, especially for low-income households. Over the last seventy years, the government has set several housing policies to increase the housing supply. The government established several housing authorities and agencies to engage multiple entities in the housing provision system. These entities included public and private organisations involved in the planning, developing, and managing of housing projects and establishing housing authorities and agencies to streamline and coordinate housing efforts involving various stakeholders. This decentralised approach improved the efficiency of housing provision. However, the housing shortage remained persistent, indicating that further measures were necessary [3,4]. Numerous housing laws and regulations have been issued, several housing programmes have been launched, and many authorities and agents have been established. However, these fluctuations have never been sufficient to satisfy the growing demand for social housing [5].

From the late 1990s until early 2014, low-income housing projects have been concentrated into two main projects, i.e., "Youth" and "Future" projects. The government established two separate authorities for each project responsible for implementing, developing, and managing it. The main difference between these projects was the source of funding. "Youth" project was funded from the revenues of sales of land plots to high-income residential developments and luxury villas and apartments. On the other hand, the "Future" project was funded by a Public–Private Partnership (PPP) between the government and private investors, with the government providing the land. Both projects supplied a total of 90,069 units in different new urban cities, mainly in Cairo, in the form of four or five-storey flat blocks of two and three-bedroom flats with areas ranging from 63 m^2 to 100 m^2. The control over these projects was stricter by preventing any alterations by the occupiers, as any modifications were immediately demolished. In addition, the urban design considered the environmental and utilisation aspects by providing more open spaces and green areas to improve the occupiers' living conditions and diversifying the facade design. Despite that and due to economic difficulties, the two projects ceased to continue after trials to decrease costs by limiting the units to smaller areas of 63 m^2 [6].

In 2014, the Social Housing Program was announced by the government to build one million low-income houses in collaboration with the World Bank, lending the government USD 500 million. However, only 12,000 units were constructed eleven months after the project commenced [7]. Moreover, in more than six years, the total number of units built was just more than 375,000 by all the government authorities [2]. Furthermore, most of the private sector's housing developments target the high-income and luxury markets, especially in the new urban communities. Therefore, to fill this gap, cheap houses are being built by the informal sector, where families build their own houses without legal permits, leading to an increase in improper housing, which is mainly considered unsafe [8].

The gap between supply and demand is expanding due to the increase in population, where the average increase rate is about 2% annually [9]. In addition, the supply rate is inefficient, as the two main projects, "Youth" and "Future", supplied about 90,000 units during their lifetimes. The backlog in housing resulting from this gap reached around three million units, as announced by the government, aiming to deliver 300,000 units annually for new households and about 254,000 units to overcome the backlog from the past. Moreover, the current low-income housing conditions have severely deteriorated due to a lack of maintenance and poverty. This generated slum dwellings that need to be replaced, although most of the population cannot afford to buy new houses where the house price to income ratio has reached 18.4 years [10].

The housing backlog in Egypt has reached 3.5 units, with the supply incapable of fulfilling the growing demand [11]. Low-income and social housing has an average annual supply of about 50,000 units, creating an estimated required annual supply of 300,000 to clear the accumulated backlog [10]. Furthermore, the insufficient supply over the past resulted in the growth of slum dwellings and informal housing that is not up to safe and decent standards and quality, which need to be replaced due to deterioration [12].

Developing social housing units using MMC approaches can positively influence the residents' social and cultural aspects. The improvements brought by MMC in terms of improved quality will contribute to increasing the residents' feelings of appreciation from decision-makers. This will reflect on their utilisation of the units, encourage them to preserve them, and increase their sense of responsibility towards the local community. According to the collected data, it is likely for the residents to accept their homes being built by this method as their primary concern is the final product. Providing homes with better quality, giving the flexibility to modify and extend, and engaging them in the decision-making process are all factors that can contribute to the success of MMC adoption in social housing.

On the other hand, the Egyptian construction sector is the fifth highest sector, adding value to the economy, with a total value reaching USD 22.4 billion in 2020 [13]. About 10% of the Egyptian workforce works in construction, leading to an average growth rate of 6% annually between 2012 and 2019 [13]. However, several challenges in the construction sector affect its performance despite its notable growth and contribution to national development. The industry is struggling from severe project delays, low productivity, poor quality, lack of technology and innovation, poor health and safety, and high rates of construction and demolition waste [14–18]. Moreover, traditional construction is the dominant method, with concrete, steel, and bricks as the primary materials used. Heavy reliance on conventional construction methods acted as a barrier to innovation in construction techniques and a need for more research and development of implementing innovative construction methods.

Productivity has always been a critical issue in construction, where it needs to catch up to other industries. Dolage and Chan (2013) argued that technology has significantly increased productivity over the last three decades through Modern Methods of Construction (MMC) [19]. MMC refers to innovative techniques and processes used in the construction industry to enhance efficiency, speed, quality, and sustainability in building projects. While MMC is not a new concept, there has been a renewed interest in adopting its approaches in recent years. This interest is driven by several factors, including technological advancements and a growing awareness of the need for more sustainable construction practices. One of the key drivers behind the increased interest in MMC is advancements in technology. Over the past decade, significant developments have been made in digital design tools, building information modelling (BIM), robotics, automation, and prefabrication [20]. These technological advancements have enabled construction companies to optimise the construction process, reduce errors, and improve productivity. For example, BIM allows for virtual design and prototyping, which helps identify and rectify design issues before construction begins, reducing delays and costs [21].

The increased interest in MMC is also driven by the need to address housing shortages and rapid urbanisation. MMC offers the potential to speed up construction timelines and deliver projects more quickly, helping to meet the rising demand for housing in many urban areas. Using standardised components and assembly processes in MMC can facilitate faster construction, allowing for the rapid deployment of affordable housing solutions. Governments, industry bodies, and construction companies worldwide recognise MMC's benefits and are actively promoting its adoption. In many countries, initiatives and policies are being developed to incentivise MMC, such as funding support, streamlined regulations, and certification schemes. This concerted effort is helping to drive innovation, collaboration, and investment in MMC technologies and approaches [21]. Many housing developers are shifting to MMC in developed countries, including the United Kingdom, the United States, Japan, and Scandinavia, by taking the improved manufacturing capabilities and digital technologies to the housing construction sector [20].

It is believed that the construction practices in Egypt need to be revised to achieve the required supply of decent housing to clear the accumulated backlog of social and low-income housing. The mass production of low-income housing units creates an excellent potential for adopting MMC approaches to increase its supply. Adopting MMC can benefit

the housing provision process and improve the performance of the construction industry. Social housing units in Egypt are designed as three-bedroom 90 m2 flats in five-storey flat blocks, providing the opportunity to benefit from the modular standardisation that MMC can bring.

Adopting MMC in the construction of low-income housing projects in Egypt requires careful consideration of the influencing factors to its implementation. The influencing factors need to be assessed according to their effect on the adoption process and whether these factors act as success factors or challenges. This study aims to develop a framework by identifying the critical success factors, challenges, and barriers to MMC adoption in low-income housing projects. In the literature, several success factors and challenges have been identified in implementing MMC in developing countries without establishing a framework that illustrates how to implement it successfully. Moreover, there is a scarcity of research in the Egyptian housing projects to adopt and implement MMC to increase the supply of housing units. Much of the literature on low-income housing projects focuses on the drawbacks and challenges of the construction sector and housing policies.

This research explores the main challenges facing the construction industry in Egypt alongside the low-income housing sector. To identify the problems that impact low-income housing projects and how they will affect the implementation of MMC and explore the factors that have hindered its implementation until now. The research aims to investigate the enabling environment to enhance MMC implementation in low-income housing and identify the relevant prefabrication approach that can be adopted. Furthermore, the purpose of the research into the critical success factors and lessons learnt from the past implementation of MMC in developed countries is to successfully develop an adoption framework for Egyptian low-income housing projects.

3. Materials and Methods

The research adopted a relativist philosophical stance with a social constructionism assumption. This philosophical stance believes that there are several perspectives on the same issue, while knowledge is gained from people's beliefs and interactions. Hence, these perspectives have guided the use of an inductive approach where the research problem has been this study's core and different data collection methods have been used. In the beginning, an extensive literature review was conducted to provide a complete overview of the Egyptian social housing and construction sectors. Moreover, the literature helped us understand how MMC originated in developed countries and identify the contributing factors to its success and the challenges and barriers to its implementation. In addition, the Egyptian housing and construction sectors were critically reviewed to discover the enabling environment of MMC and the corresponding success factors and challenges.

This research adopted a convergent parallel mixed-methods approach. The research design combines both qualitative and quantitative data to offer a comprehensive analysis of the research problem. Collecting both data types simultaneously allows their integration and interpretation, resulting in a holistic understanding of the subject matter. Qualitative and quantitative research methods were merged to gather data through fifteen semi-structured interviews with construction professionals, government officials, and precast factory managers. A stakeholder's mapping process selected the participants of the interviews to identify the relevant stakeholders in the low-income housing provision projects. A questionnaire survey was the instrument for the quantitative data collection to gather data from the residents of two social housing case studies. The final stage of data collection was to verify and validate the adoption framework by interviewing construction management experts and academics.

4. Data Collection and Analysis

Qualitative and quantitative data analysis was used in this research. Qualitative data were reduced through editing, segmenting, and summarising. The primary goal was to reduce the data without sacrificing any information. Subsequently, coding was applied to

identify themes, clusters, and patterns. The interviews were transcribed and translated from Arabic to English. The translated interviews were then imported into NVIVO software version 12 for coding, clustering, and creating themes and patterns. On the other hand, descriptive and statistical analysis were used for the quantitative data, where the Kruskal–Wallis test was used to evaluate the differences between the residents' responses.

4.1. Qualitative Data

Interviewees were senior managers and directors with various roles, including government officials, contractors, consultants, and house designers. Most of the participants, 80%, have more than ten years of professional experience in order to have in-depth knowledge of the housing process and a decision-making role. Moreover, 73% of the participants were from the private sector, and 27% were from the public sector because contractors from the private sector are the prominent builders of low-income and social housing in Egypt. The government procures the majority of public housing projects to private contractors, so it is essential to know their experiences and knowledge of the process. This variation in roles and experiences was to obtain different views and opinions. The interviews were semi-structured, with open-ended questions to provide flexibility and in-depth discussions about the practices of low-income housing projects. The questions were designed according to findings from the literature review on adopting MMC. The interview questions were divided into three main parts: challenges, barriers, and success factors.

The researcher approached the participants according to their points of contact and personal relations from past experiences. The participants were recruited according to their work experience in public housing projects and to be in senior positions. The researcher has reached out to as many people as possible from different backgrounds according to the stakeholder mapping in order to collect all the required information. In addition, after each interview, the participant was asked if they could provide contact details for any potential person to interview.

The interviews developed a large volume of qualitative data that required precise data analysis. The transcripts have been inserted into NVivo software for the qualitative analysis. Each transcript has been read thoroughly to identify the key themes and patterns arising from the different opinions of the participants. Patterns that emerged from the transcripts were given specific codes relevant to the research questions and objectives. The codes were grouped into three main groups: 1. barriers; 2. challenges; and 3. critical success factors according to the participants' views and opinions of the potential uptake of offsite prefabrication in housing projects. The grouping of the codes is shown in Figure 1. In addition, Table 1 presents examples of the quotes extracted from the interviews based on thematic analysis.

Table 1. Thematic analysis of qualitative data.

Themes	Subthemes	Quotes from the Interviews
Barriers	Capital costs	*In order to have this cost absorbed you need to secure a high volume of units to be built. I mean that as a contractor or developer, you have to secure contracts with the government to build a high volume of units in order to have the high initial cost absorbed with a large number of units manufactured and built.*
	MMC knowledge	*The organisation that plans to present this method needs to market its product and show off its capabilities, specifications and model. I think the organization has to make a marketing plan through conferences or shows to introduce it to the public alongside construction experts. This can be done as well by building a model or a whole building to present it and introduce it to people showing its advantages, specifications and how this method can improve the construction process.*
	Social factors	*We have had cultural and social problems since the Pharaohs! We currently occupy only 6% of Egypt's total land area. When children start to grow up, starting to live independently and getting married, they want to live next to their parents. In the same street or even in the same building. The government tries to convince them to move to new urban developments, but they refuse and start making excuses such as lack of schools and transport. Then the government provides all that, but they hardly go, it's in their beliefs.*

Table 1. *Cont.*

Themes	Subthemes	Quotes from the Interviews
Challenges	Construction industry capabilities	*Our construction industry capabilities did not reach the required level to adopt MMC. It requires high-tech tools, experienced workers, and knowledgeable engineers, and Egypt currently lacks all of that. MMC will create economic and technical challenges that exceed the current construction industry capabilities.*
	The private sector	*What actually happens here in Egypt is that small contractors enter into low-income housing projects with the government or local councils to increase their business capacity and grow through traditional and easy work. It provides them with experience and knowledge as small companies and, of course, increases their profits. They will start to have a strong financial position to invest in their property development projects, gaining larger profits reaching 200–300%. So, mainly working in social housing is a stage to increase their portfolio; nobody wants to invest in social or low-income housing*
	Resistance to change	*It needs to emerge gradually. Workers can take courses and training on the new method, but they will need to become more familiar with it. In order to avoid resistance to change, as I said, it needs to be gradual, and I must bring an experienced worker to work with this method. He will teach it to other workers practically then this team will grow to create an experienced team that I can depend on. This team will be an experienced team who got used to this method and can then pass their knowledge to other teams*
Success factors	Sustainability	*There's the environmental factor too, here in Egypt, we do not consider thermal and sound insulation really much. Unlike European countries for example, the main structural material is timber, however, houses are thermally insulated in addition to installing heating systems. We do not do that here. As long as it basically functions well as a house then that's it.*
	Industrial capabilities	*We have here many factories like cement, steel, marble, etc. In all construction aspects, we have several factories and some factories export to the Middle East and even Europe, like the AL-Jalala marble factory that exports to MENA and France. When it was found that there was feasibility for it, the Jalala factory was built with one of the largest product lines in the MENA.*
	Governmental support	*I told you that a committee from the Ministry of Housing must be convinced with this method. He does it himself and convinces this committee that this method has been applied in developed countries. He saw it there once from an Egyptian point of view and convinced them that this subject would benefit Egyptian policy from a nationalist point of view.*

4.2. Quantitative Data

The main aim of the questionnaire is to explore and identify the challenges and drawbacks of the current social housing units from the residents' point of view. In addition, investigate their needs that their units are not satisfying, as well as their expectations of living in prefabricated units. Understanding the occupiers' requirements and beliefs can help develop the framework to efficiently implement MMC in low-income housing projects by exploring mitigating factors that can hinder the successful implementation of MMC. The questionnaire consisted of three main sections in the form of a five-point Likert rating question about rating their doubts against prefabricated houses, ratings of their current homes, and finally, ratings of important factors affecting their decision on choosing their new homes.

A case study survey has been performed with residents of two social housing projects in different locations in Egypt to identify the challenges and needs of the residents in their social housing houses. Two case studies have been selected, the first in El-Salam district in Cairo and the second in Tenth of Ramadan city in Ash-Sharqia Governorate. The two case studies have been chosen in different locations to provide a broader view of all the factors affecting the residents in social housing projects. The targeted sample size was calculated from the Saunders et al. (2023) table of the sample size of the target population at a 95 percent confidence interval [22]. The total number of flats (2472 + 2688 = 5160 flats) is the sampling frame; therefore, the minimum sample size is approximately 360 units. A total of 141 questionnaires were collected from residents of both case studies from the 360 questionnaires required according to the sample size, with a response rate of 40.3%.

Respondents were selected by systematic random sampling technique. Systematic random sampling (SRS) involves selecting a sample from the sampling frame in regular intervals calculated by the following steps [23]:

- Identify the sample frame.
- Identify the sample size.

- Calculate the sampling fraction (n = population ÷ sample).
- Select a starting point from the first five cases.
- Select case every nth case.

Challenges	Construction industry capabilities	
	Coordiantion	
	Costs	
	Funding and finance	
	Construction performance	
	Housing policy	
	Private sector	
	Resistance to change	
	Skills and training	
	Technology	
Barriers	Capital costs	
	Contracting companies	MMC acceptance
		Unemployment
	MMC knowledge	
	Social factors	
	Social housing contractors	
	Building codes and policies	
Success Factors	Architectural design	Design standards
		Heritage
		One form of design
	Expansions and modifications	
	Sustainability	
	Governmental support	
	Housing types	
	Industrial capabilities	
	Maintenance	
	Quality	

Figure 1. Codes extracted from the interviews.

For each case study, the number of units is the population where the cases were selected according to the calculated sampling fraction. The sample fraction is as follows:

- N = 5160 ÷ 360 = 14.

Every 14th unit was selected to participate in the survey by asking the adult living in the household face-to-face to complete the questionnaire.

Invitation flyers were distributed by depositing them into the mailboxes of selected respondents. The flyers were distributed by an authorised person from the researcher, who provided him with a map of the selected area and the selection criteria. The sampling fraction was decreased to increase the number of distributed flyers to avoid a reduced response rate due to the change from face-to-face to mail distribution. Decreasing the sampling fraction by 25% resulted in distributing the flyers to 1440 flats (360 × 4 = 1440). The flyers were printed in A5 size containing a QR code to ensure easy access to the survey by the respondents. The respondents were asked to provide the flat and building numbers without including personal or sensitive data in the questionnaire to provide access to any selected survey if required by the researcher.

Statistical analysis is used to identify any significant differences in the perceptions of the respondents with respect to their skill level. It is assumed that each skill level will have their own specific vision and attitudes towards their housing needs and challenges. It is crucial to have an in-depth understanding of the residents' needs and challenges in their current and future housing. In order to provide this, the responses of the residents were grouped into three main groups according to their skill level. Each group is believed to represent a social class according to their knowledge and awareness. The differences between these three groups would shed light on specific social or cultural understandings and beliefs that could differ from the other groups. Identifying these differences helps formulate the framework to address the challenges and needs of the residents of low-income housing projects on all levels. Thus, the respondents were grouped into three groups according to skill level: highly skilled, semi-skilled, and lowly skilled. The grouping was based on the occupation of the respondents, as shown in Table 2.

Table 2. Grouping of the occupation of the respondents.

Highly Skilled	Semi-Skilled	Lowly Skilled
Self-employed	Labour	Housewife
Lawyer	Employee	Unemployed
Engineer	Driver	Student
Carpenter		
Teacher		
Factory manager		

The results of the tests were compared to the corresponding Chi-squared critical value according to the degree of freedom of this study in order to accept or reject the null hypothesis. The corresponding degree of freedom (df) for this study is calculated at three groups—1 = 2 (df). The KW test is calculated through the following equation:

$$H = \frac{12}{n(n+1)} \sum_{j=1}^{c} \frac{T_j^2}{n_j} - 3(n+1)$$

n = sum of samples for all samples;
c = number of samples;
T_j = sum of ranks in the jth sample;
n_j = size of the jth sample.

If the static value H is larger than the corresponding Chi-squared table value, then the null hypothesis can be rejected, meaning that there are significant differences between the three groups. If the H value is smaller than the corresponding Chi-squared table value, then the null hypothesis can be accepted, stating that there are no differences in the perceptions of the respondents. The questionnaire considered three main aspects related to this study, which are discussed in the following sections.

4.2.1. Residents' Concerns from Prefabricated Houses

The means of the respondents' ratings were calculated from the three groups: highly skilled, semi-skilled, and lowly skilled. The means of all groups were sorted from the highest mean to the lowest, as shown in Figure 2. The hypotheses for the test were as follows:

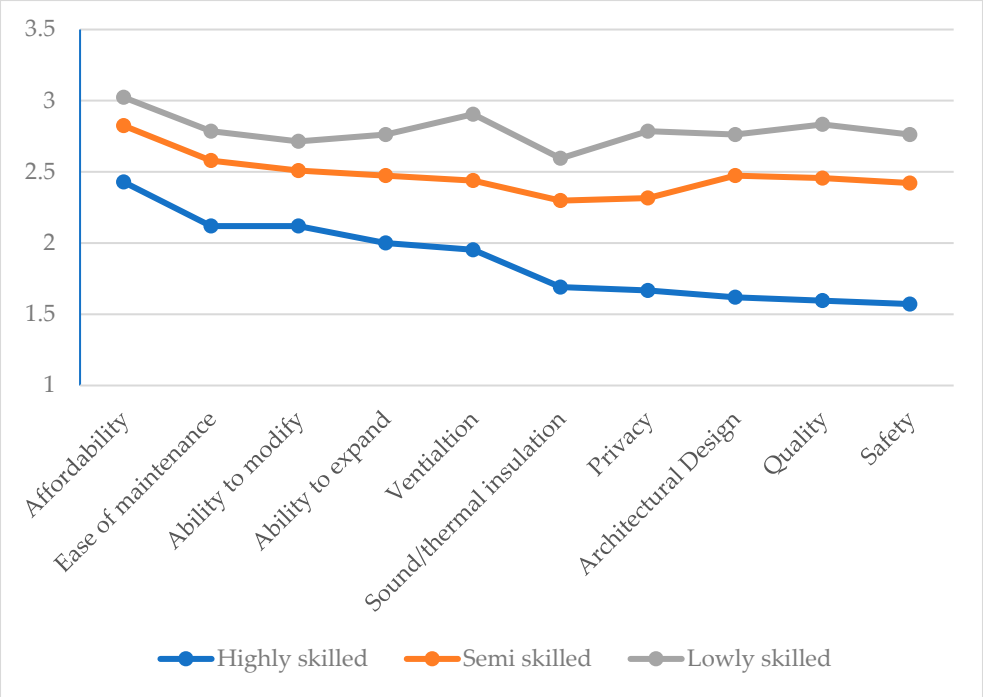

Figure 2. The mean ratings of the concerns from MMC of all groups.

H1. *Null Hypothesis: all the residents have similar concerns.*

H2. *Alternative Hypothesis: at least one group has different concerns than the rest of the residents.*

The H value for the test was 23.32, and the Chi-square table value is 5.991 at a 95% confidence level with the corresponding degree of freedom (df) calculated at three groups—1 = 2. Hence, the H value was greater than the table value. Therefore, the null hypothesis can be rejected. According to the test result, there are notable differences in their concerns towards MMC, where the highly skilled group showed lower concerns about MMC than the other two groups. These differences require wider consideration of all the doubts and concerns of MMC before implementing it in low-income and social housing projects to avoid harder resistance from the residents.

4.2.2. Ratings of the Current Homes

The mean values of the rating from each group were calculated and sorted from the highest to the lowest as shown in Figure 3. The values were combined in one table accordingly to calculate the H value and its corresponding Chi-square table value to accept or reject the hypotheses, which are as follows:

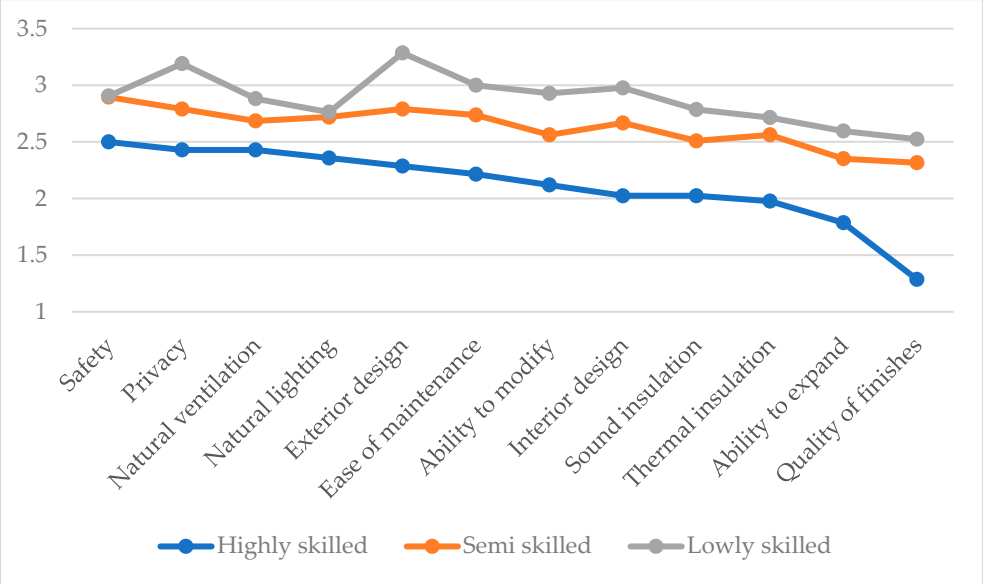

Figure 3. Residents' average evaluation of their current homes.

H3. *Null Hypothesis: There is no difference in the resident's evaluation of their current homes.*

H4. *Alternative Hypothesis: at least one group has a different evaluation than the rest of the residents.*

The H value for the test was 24.29, and the Chi-square table value is 5.991 at a 95% confidence level with the corresponding degree of freedom (df) calculated at three groups—1 = 2. Hence, the H value was greater than the table value. Therefore, the null hypothesis can be rejected. The KW test was performed to identify if there are notable differences in the residents' opinions about their current homes and their evaluation. The result confirmed that there are significant differences requiring more attention to a wider set of factors to consider in order to tackle the challenges and disadvantages of the current housing. This will help provide a more precise framework that satisfies the actual needs of the residents, thus increasing the possibility of successful implementation and adoption of MMC in low-income housing projects.

4.2.3. Rating of Factors in Choosing Future Homes

The mean values of the rating from each group were calculated and sorted from the highest to the lowest as shown in Figure 4. The values were combined in one table accordingly to calculate the H value and its corresponding Chi-square table value to accept or reject the hypotheses, which are as follows:

The H value for the test was 2.69, and the Chi-square table value is 5.991 at a 95% confidence level with the corresponding degree of freedom (df) calculated at three groups—1 = 2. The H0 cannot be rejected, and therefore there are no significant differences between the three groups. The KW test was performed in order to identify any notable differences in the main factors that the residents take into consideration when choosing their new homes. The result determined that there are no significant differences in the answers of the three groups, which means that the overall decisive factors are convergent. These factors identify the actual needs of the residents when choosing their new homes and their priorities. The results will help aim the framework to adopt MMC in low-income housing to satisfy the users' needs and underpin the critical factors that support efficient utilisation of prefabrication for the users.

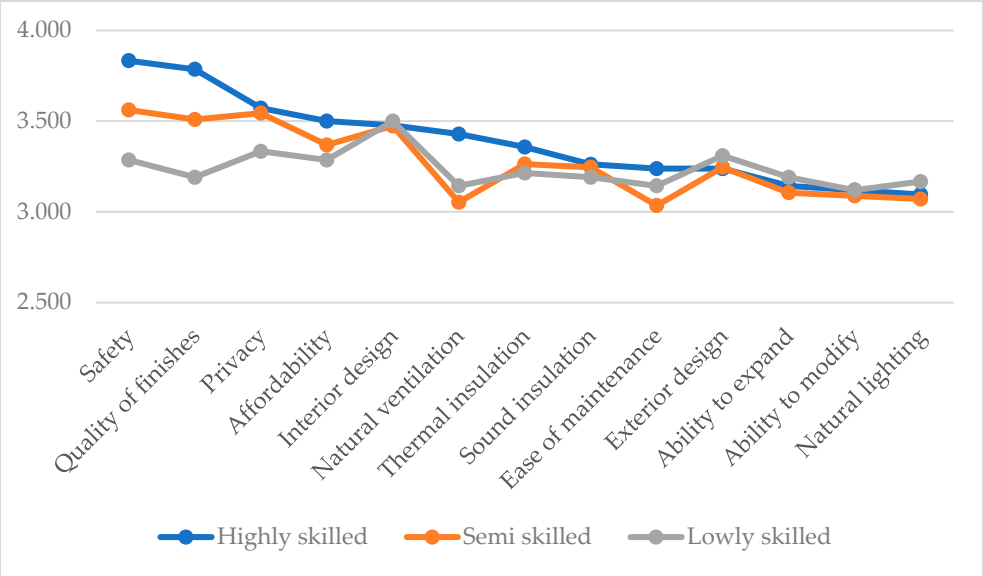

Figure 4. Residents' priorities when choosing new homes.

H5. *Null Hypothesis: All groups have the same influencing factors when choosing their new home.*

H6. *Alternative Hypothesis: At least one group has different evaluations when choosing their new homes.*

5. Discussion

In general, the results of the analysis of the collected data and the literature review showcased the relationships between the influencing factors and how they act as success factors, challenges, or barriers to implementing MMC in social housing projects. The findings showed the problems that might arise from adopting MMC and how they can be mitigated or eliminated. The stakeholders in the social housing provision system have been identified and what roles they could play in adopting MMC to implement it successfully. The relationships between factors and the information from the arguments allowed the researcher to formulate an adoption framework that considers the key factors affecting the implementation of MMC in social housing projects.

5.1. Critical Success Factors

Certain success factors can prompt MMC implementation in Egypt's low-income housing projects. These factors have been identified from the literature and the analysis of collected data. Modularisation and standardisation are success factors of MMC, corresponding to the nature of social housing projects. Social housing projects are designed in a single form of two- and three-bedroom flats. Implementing MMC in social housing will benefit from the modularisation advantage of producing modular units offsite and then transferring them to the site for installation.

Moreover, MMC can address the loss of architectural heritage through the modularisation of exterior elevations, which could be cheaper with the manufacturing production of units. Manufacturing architectural components could give architects better abilities to produce forms corresponding to any specific architectural style. Furthermore, MMC can provide more design flexibility to meet residents' needs for expansions and modifications. Achieving these benefits could gain the government's support to encourage the implementation of MMC by increasing the supply of housing units and improving its performance.

Governmental support is a critical factor for MMC to be adopted and succeed in Egypt. The government can support MMC adoption in social housing projects in several ways:

- Develop policies that encourage the use of MMC approaches in social housing projects.

- Provide incentives for developers to stimulate investment in MMC for social housing projects.
- Secure enough units for the private sector implementing MMC to help absorb the high initial capital required for manufacturing facilities.
- Increase the awareness and knowledge of MMC to avoid the negative perception that might hinder its implementation.
- Ensure the engagement of social housing users in the decision-making process of developing new social housing units using MMC, considering their social and cultural requirements as well as their concerns and doubts.

MMC can support housing policies and the housing provision in Egypt by addressing the shortcomings in implementation. One of the main issues in low-income housing policies is the private sector's reluctance to invest. According to the latest housing strategy, the government plans to introduce policies encouraging the private sector to participate in low-income housing through developing Public–Private Partnerships [5]. These partnerships can be set up to adopt and implement MMC in low-income housing, taking advantage of its faster build, improved quality, and cost-effective solutions. The initiative to adopt MMC with the SHMFF can benefit the private sector from tax cuts, subsidies, and low interest rates provided by the SHMFF law.

In the current housing strategy set by the Ministry of Housing, one of the main pillars is to prompt innovative housing in affordable housing. Introducing MMC to housing authorities as an innovative approach to executing low-income housing projects can achieve the governmental officials' support. The construction with MMC will be considered very advanced compared to the current construction methods used in social housing units. Through MMC, several goals of the Egyptian housing policy can be achieved, such as increasing the supply of housing units, improving the quality and efficiency of units, and diversifying the units' areas and designs to accommodate the users' growing needs. From the analysis of the interviews, it has been emphasised that introducing MMC to housing authorities and government officials will be supported as innovation and sustainable approaches are currently promoted by the country's leadership. However, to succeed in implementing MMC in social housing, knowledgeable leadership is essential to deal with the housing authorities, who can deal with their tough mindset and the inherent bureaucracy. Managing the change in implementation will be challenging for the entity willing to adopt MMC in social housing projects. They will need to deal with behavioural change with the decision-makers and manage their resistance to the difference in the construction methods.

Although the country has set several environmental goals to achieve by 2030 according to its Egypt 2030 policy, sustainability is a derelict topic in social housing projects. Egypt's 2030 environmental policy aims to increase its dependence on renewable and clean energy resources, reduce carbon emissions, and minimise waste. However, the construction industry still produces vast amounts of construction and demolition waste, contributing to environmental contamination. Construction waste has reached 40% of the total construction materials, where it is dumped either on roads or in inefficient dumping sites, lacking precautionary measures to prevent waste burning and environmental pollution [18]. In social housing units, unsustainable construction has increased renovation requirements due to the use of non-durable materials. In addition, the units lacked insulation materials that could prevent excessive heat in the summer, which required installing air conditioning units to cool them indoors. Traditional construction approaches are incapable of achieving sustainable solutions in social housing units. It has been indicated that conventional methods increase the possibility of construction waste in addition to unproviding sustainable units that can reduce energy consumption. In social housing projects, it is necessary to provide cost-effective and sustainable solutions to lower utilisation costs, not only construction costs. This will help increase the affordability of units for low-income residents and improve their living conditions. MMC can enhance the sustainability of social housing projects and units by reducing construction waste and integrating manufacturing capabili-

ties into the construction process. Innovating the housing provision system through MMC can be a practical tool to tackle the construction industry's sustainability challenges.

Due to the complexity of adopting MMC and the requirement of large investments, the public sector should develop partnerships with the private sector while providing them with guaranteed financial and execution security.

From the literature review findings and the data collection, the current improvements in the physical infrastructure and the development of manufacturing facilities could create an adequate enabling environment to implement MMC. The availability of manufacturing capabilities alongside developed infrastructure in new cities and improved road networks has been determined to be a critical success factor for MMC implementation. In addition, the current precast concrete factories manufacturing precast concrete panels widely used in road and bridge construction could be developed to accommodate MMC for social housing units using the same technology. These factories can manufacture floor, wall, and ceiling panels for housing units and create volumetric modular pods to be transferred and installed onsite.

Achieving sustainability in social housing units would be one of the critical success factors for MMC. The country is currently taking serious steps to achieve its sustainable development goals, including encouraging innovation and technology and improving its sectors' environmental performance. Implementing MMC can help in attaining SDS goals through the transfer of MMC technology to the social housing sector. MMC can address the housing shortage by increasing the supply of units to provide decent housing to a larger segment of the least advantaged households. Furthermore, it can help improve the sustainability performance of the construction sector by reducing construction waste and improving the quality and energy performance of social housing units. These factors meet the overarching goals of SDS, Egypt 2030, and the Egyptian housing policy, making them one of the critical success factors for MMC.

Developing partnerships with the private sector would enhance the implementation of MMC, making it one of the main factors for its success. Public–Private Partnerships (PPPs) would bring mutual benefits for the private and public sectors to implement MMC in social housing units. These benefits include increasing the supply of social housing units, relieving the financial burden on the government, and encouraging the private sector to invest in social housing by providing them with financial incentives and tax reliefs allowed by the current SHMFF law. This is because it will be challenging for the private sector to adopt MMC without the support of the public sector represented in the housing authorities to reduce the financial risk of the high initial capital in addition to securing large quantities of units. On the other hand, the public sector will not adopt MMC independently. The initiative to adopt it will come from the private sector, as the government only provides plots of land and then contracts with contractors from the private sector to construct social housing units.

5.2. Challenges

The data analysis shows that the construction industry suffers from poor quality, low productivity, health and safety issues, project delays, waste, and sustainability issues. Furthermore, there are more than 32 causes of construction delays, the most significant being financial difficulties, poor quality, low quality of construction materials, total workforce, COVID-19 pandemic, corruption, and tendering strategies [14,24]. In addition, the industry's severe health and safety issues were mentioned both by the interview participants and in the literature. These issues have caused the construction industry to underperform despite being one of the top sectors contributing to the Egyptian economy. The industry needs innovation and sustainable approaches to address these issues and improve performance.

The dominant construction method in residential projects is traditional, either in low-income and social housing or in high-end and luxurious projects. Social housing contractors employ the most cost-effective construction method without consideration of any other approach. However, from the interviews and the literature review, social housing units

have the lowest quality finishings, and the number of units built annually has been less than half of the planned. Throughout the past five decades, traditional construction methods have not been sufficient to reduce the housing shortage and increase its supply. Other countries have been in the process of adopting offsite prefabrication in order to increase the supply of housing and improve the performance of the construction industry. As illustrated in the literature, benefits from offsite prefabrication include improving quality, reducing construction duration, improving health and safety, and improving overall construction performance. These benefits are crucial for the Egyptian housing sector, which is already struggling in those areas.

Adopting MMC in social housing projects comes with numerous challenges that would hinder its successful implementation. Adopting MMC would be challenging concerning the current capabilities of the construction industry, especially among social housing contractors. Traditional construction is the sole method used to construct social housing units. Lack of innovation and technology in the construction industry will result in complications in transferring MMC technology to social housing projects. In addition, the need for more competencies and expertise, from the workers to the senior management, of MMC requirements in coordination and quality control would be another challenging factor. However, adopting MMC could upgrade the construction industry's capabilities to improve its performance with an experienced leader with the tools and expertise to coordinate and manage the implementation process from its inception to completion.

The high initial capital of establishing prefabrication factories to manufacture MMC components is the main challenge to its adoption. The government is struggling with economic challenges of high inflation, currency depreciation, the effects of the COVID-19 pandemic, and the Russian–Ukrainian war. On the other hand, the private sector is facing economic challenges, too, including increasing prices and high inflation rates. Social housing contractors cannot afford such high capital to support the implementation of MMC factories and their running costs. To adopt MMC in social housing projects, the unit cost should meet the current cost of traditionally built units, which the cooperation of the private and public sectors can only achieve. This can be achieved by securing a large number of units in addition to using local materials and minimising the need to import any components as much as possible. Furthermore, private sector developers are only interested in investing in high-end and luxurious residential developments where it is much more profitable, according to the literature and the data analysis. Getting the private sector to invest in social housing projects would be one of the critical challenges where they must ensure substantial profits as much as they gain in luxurious developments.

Developing partnerships with the private sector would enhance the implementation of MMC, making it one of the main factors for its success. Public–Private Partnerships (PPPs) would bring mutual benefits for the private and public sectors to implement MMC in social housing units. These benefits include increasing the supply of social housing units, relieving the financial burden on the government, and encouraging the private sector to invest in social housing by providing them with financial incentives and tax reliefs allowed by the current SHMFF law. This is because it will be challenging for the private sector to adopt MMC without the support of the public sector represented in the housing authorities to reduce the financial risk of the high initial capital in addition to securing large quantities of units.

From the literature review and data analysis, one of the main challenges to adopting and implementing MMC in housing is the negative perception and lack of awareness. Egypt's case would not be different; it is expected for MMC units to face resistance to its implementation from the workers and the residents. Although the resistance to change from the residents will be insignificant, where their primary concern is to obtain decent housing regardless of its construction method, it is expected to be more from the local workers. As previously discussed, most construction workers gain knowledge from their peers without proper technical education. It would be difficult to change their mindsets

and the techniques they used to work with, which they learnt from the beginning of their career, usually starting at a very young age.

Egypt is a conservative Muslim country where Islamic practices and behaviours are highly respected culturally by most of the population. More than 90% of the population are Muslims, and the rest are Christians, with both religions practised moderately daily. These practices are reflected in the Egyptians' houses and way of living; for example, in house designs, they are eager for increased privacy by using mirrored glass for windows instead of clear glass in Western countries. Unlike Western communities, families are considered to have strong correlations, where teens tend to stay with their families until they become married. In addition, newly married couples from medium- and low-income communities live with their parents, which is also due to being incapable of buying or renting new houses, leading to overcrowding [25]. These cultural aspects affect the way of living, which decision-makers and designers must consider. Neglecting these factors has failed in several housing development projects, according to Ahmed (2012) [6], due to not participating in the community in the planning and implementation of such projects.

The growing family needs must still be satisfied in the current social housing units. The main issue is that the residents are not involved in the design process of social housing projects, leading to gaps between the design and function of housing projects. Moreover, Egyptians are strongly connected to their habits and traditions where they require more privacy in their houses, for example, reflecting glass windows instead of transparent glass in their homes. They tend to separate their living areas from the guest rooms, where they decorate them in a more valuable manner to show their most valuable belongings. The resident's social behaviour plays a significant role in the housing provision system. It has been concluded from the interviews that in new urban communities, the residents do not have strong local ties to the environment that encourage them to preserve it. This can be deduced from the feeling that this place does not belong to them, or they feel like expats, which is not their usual settlement. The features of the built environment and the involvement of the residents in structuring it play a significant role in creating social ties to the community, which has been observed in informal settlements the residents built [26]. Developing communities that satisfy the users' needs and meet their social and cultural beliefs create stronger local ties to the community, leading to preserving their units and helping to reduce their deterioration, which, subsequently, supports reducing the housing shortage.

The scarcity of technical education and training facilities within the construction sector will make it challenging to adopt MMC. MMC requires a high level of skills and training due to the complexity of its manufacture and assembly. The issues of poor quality and low health and safety performance in the Egyptian construction sector must be addressed before implementing MMC, as it might cause severe problems during onsite assembly and handling. Although unskilled workers are abundant due to the high unemployment rate and high population, it is challenging to train and qualify the required number of workers without developing proper training facilities.

Although the country is on the way to achieving its sustainable development plan, where one of its main pillars is promoting technology, innovation, and digitalisation, in practice, the construction and manufacturing sectors are still behind in implementing technology and innovation. Technology transfer in the social housing sector will be challenging due to the lack of technological readiness. It relies only on manual handling and traditional construction methods, in addition to the lack of digital infrastructure. MMC is considered an advanced innovation in the current social housing construction environment, creating a high challenge to its implementation without considering the capabilities and knowledge of the current practitioners. This has been reflected in the limited adoption of MMC approaches in the Egyptian construction industry of precast concrete panels used in civil works.

5.3. Barriers

The data analysis and literature review identified several factors as foreseeable barriers to MMC adoption in social housing projects. Firstly, contracting companies operating in social housing projects would only accept MMC as a construction method if they were familiar with it. From the qualitative data analysis, it has been identified that the contractors working in social housing projects are small contractors, mainly employing traditional methods that their workers have learnt from their predecessors. They are expected to have inflexible mindsets that make it hard to accept change in methods. Moreover, there would be speculations that MMC would lead to unemployment among social housing workers as manufacturing would replace their skills, and they would not be needed anymore.

In the same context, a lack of knowledge about MMC would be a barrier to its implementation as well as a challenge, as previously mentioned. It would cause several hindrances to its implementation among decision-makers, workers, residents, and financial institutions. Knowledge of MMC needs to be shared among all stakeholders, emphasising the advantages and benefits it could bring to the social housing and construction sectors. Accepting MMC would be one of the main barriers to its implementation in social housing projects, requiring strong leadership and project management skills to manage change with the contractors and the workers.

These barriers are interrelated with the Egyptian workers' and residents' social and cultural aspects. Change management is required to address the abovementioned barriers, including the lack of MMC knowledge, the resistance to change, and rigid mindsets. According to Lines et al. (2015), precise change management is required while implementing a new practice to assist the transition from traditional approaches simultaneously [27]. Change management agents may be necessary to foster the implementation of MMC within SHC to mitigate the effect of change on the stakeholders. The main task of these agents is to deal with the framework's short- and long-term goals and manage the coordination between different organisations.

Furthermore, the capital costs of MMC would be one of the main barriers to its implementation as well as a challenge. Securing the initial funding to establish the required facilities to implement MMC would be extremely difficult, especially with the Egyptian economy's current economic challenges. It is believed that social housing contractors (SHC) do not have the economic capacity to fund the capital costs of MMC. This would require collaboration between the private and public sectors to invest this capital to reduce the financial risks of MMC implementation.

6. The Framework

Considering all the factors, the proposed framework in Table 3 consists of seven main pillars. These pillars consider the critical success factors, challenges, and barriers, including the implementation phases, to ensure the successful adoption of MMC in social housing projects. The framework is based on the findings from the literature review analysis and the findings of the qualitative and quantitative data analyses.

Table 3. The framework for adopting MMC in social housing projects.

Pillar	Objective	Activity	Key Stakeholders
Costs	• Ensure the cost of prefabricated units is less than traditional methods. • Absorb capital costs by securing contracts with a large number of units.	• Establish partnerships with the private sector to build social housing units. • Secure contracts with a large number of units.	• SHMFF • Social housing contractors (SHCs)

Table 3. *Cont.*

Pillar	Objective	Activity	Key Stakeholders
Skills and training	• Increase training facilities for SHC. • Train and develop unskilled workers available in abundance. • Modernise current construction methods.	• Provide training support to SHC. • Provide technical education incentives to SHC.	• SHCs • SHMFF • Education providers
Architecture design	• To restore the architectural heritage. • Provide more flexibility for expansions and modifications. • Increase the users' satisfaction.	• Improve the architectural design of interiors and exteriors. • Work on more flexible design of units. • Increase the variations of designs. • Involve the residents in the early design stage.	• Designers • Social housing residents • Local councils • SHMFF
Governmental support and policies	• Increase knowledge and awareness of MMC. • Encourage SHC and the private sector to invest in MMC. • Improve the sustainability of the social housing projects in the construction and utilisation phases. • Improve the health and safety performance of social housing projects. • Ensure addressing the specific needs of the residents in each area according to their local environment and culture.	• Include MMC in social housing policies. • Provide financial incentives to the private sector and SHC implementing MMC. • Ensure sustainability and cost efficiency through MMC in social housing. • Ensure health and safety aspects in the construction of social housing projects through MMC. • Develop policies that consider cultural and social aspects of the residents, including diversity.	• Housing authorities • SHCs • SHMFF
Social and culture	• To reduce resistance to change. • To ensure good quality in manufacturing or assembly. • To increase the adaptability and satisfaction of residents and workers.	• Residents: • Increase the safety and privacy aspects of social housing units. • Increase knowledge and awareness of MMC. • Workers: • Attract the younger generation of workers to learn MMC methods. • Ensure strong local leadership and supervision.	• Project managers • Designers • SHCs • SHMFF
Technology	• Ensure full coordination between stakeholders through BIM approaches. • To cope with poor technological readiness. • Gradual adaptation to MMC approaches.	• Utilise BIM software from the design stage in social housing projects. • Ensure gradual technology transfer. • Employ available prefabrication manufacturing capabilities and modernise them.	• Manufacturers • SHCs • Designers • Project managers

Table 3. *Cont.*

Pillar	Objective	Activity	Key Stakeholders
Manufacturing industry	• Gradual adaptation to MMC approaches and upgrading of current manufacturing facilities. • Encourage manufacturers and SHCs to invest and implement MMC in social housing. • Improve quality control measures and ensure robust coordination between factories and construction sites.	• Utilise the current precast factories to adopt MMC in social housing. • Launch new social housing projects close to current industrial cities. • Provide strong project management and leadership.	• Manufacturers • SHCs • Private sector investors • SHMFF

The main influencing factors identified from the data analysis and the literature are the critical pillars of the framework. As shown in Table 3, the framework provides a series of activities linked to a set of objectives that influence the implementation of MMC. For each factor, specific objectives are to be achieved by implementing the relevant activities by the relevant stakeholders. The framework presents a holistic approach that covers all corresponding factors affecting the adoption process of MMC. It focuses on the challenges and barriers of the housing and construction sectors and how they can be addressed. In addition, it concentrates on the critical success factors that will help achieve the successful implementation of MMC.

6.1. Factor–Pillar Relationships

Certain factors influenced each pillar's activities and objectives by considering success factors, challenges, and barriers. The factors are interrelated to the activities and objectives, both directly and indirectly. Thus, it is essential to show the connection between all the elements as a whole to provide a clear understanding of the implementation of the framework. The relationships between the factors and the pillars are discussed below.

6.1.1. Costs

The first pillar is concerned with the initial funding and high capital costs, which are the main challenges and barriers to the framework. The objectives of this pillar are based on the findings of the qualitative and quantitative data analysis. The main factor of concern was that the cost per unit of MMC does not exceed the cost of traditionally built units. In addition, according to Table 3, affordability was the highest concern of MMC from the residents. Thus, it is crucial to ensure that the construction costs of MMC units do not exceed those of traditional units. It could be achieved by securing a large number of units for the entity implementing MMC in social housing projects to absorb the high capital costs. Moreover, a partnership between SHMFF and SHC is one of the main success factors for MMC to help secure the initial funding required to establish the manufacturing facilities of MMC in addition to the governmental support represented in the financial incentives and policies to include MMC in social housing projects.

The key stakeholders of this pillar are the SHMFF and SHC, where their partnership would help minimise the challenge and barrier of high capital costs and initial funding. This partnership would reduce the financial risk by distributing it to both parties by securing a large number of units to absorb the high initial capital and benefit from the tax reliefs and financial incentives that SHMFF could provide to the framework.

6.1.2. Skills and Training

The second pillar addresses the identified challenges of the construction industry's capabilities. Several factors have influenced the second pillar, including the lack of training facilities from the private sector and poor technical education. This pillar aims to improve the performance of the Egyptian construction industry through the implementation of

MMC in social housing projects. This would happen through the collaboration between SHMFF, SHC, and education providers to work on several axes related to training and skills. SHMFF would provide incentives to SHCs to increase their training facilities to develop MMC knowledge and skills in their current workforce. Moreover, SHMFF and education providers should develop technical education facilities to include MMC's technological knowledge for novice construction workers.

This pillar combines the critical success factors of governmental support, which includes providing training incentives and the abundance of unskilled workers with the challenges of lack of training and poor technical education to achieve successful implementation of MMC and help in improving the performance of the Egyptian construction industry. Achieving this pillar's objectives would support leveraging MMC's skills and knowledge in the Egyptian construction industry and, consequently, improve its capabilities.

6.1.3. Architecture Design

The architecture pillar considers several factors that would support the implementation of MMC by combining the success factors identified from the data analysis and the residents' challenges and needs as identified from the quantitative analysis. Architectural designers would collaborate with the SHMFF, local councils, and residents to improve the liveability and function ability of social housing units, emphasising the residents' social and cultural requirements, including the growing family needs. The pillar considers the lack of awareness and knowledge of MMC among the residents, where house designers will work closely with the residents to raise their knowledge of MMC and the advantages it could bring to their living conditions. In addition, the designers should work with local councils to increase the variations in design in accordance with the specific requirements of each area in order to consider the social and cultural differences between different regions.

The standardisation and modularisation factors are considered success factors in the architecture pillar by benefiting from the single design form of social housing units. To achieve this, designers and SHMFF should consider MMC in the early design stages to identify the maximum potential of MMC technology that could be adopted in social housing projects. Furthermore, the architectural heritage is also considered, where the designers include the architectural components corresponding to the Egyptian heritage in social housing projects in cooperation with SHMFF while ensuring that the overall costs do not exceed the cost of traditional construction methods.

6.1.4. Governmental Support and Policies

The governmental support pillar considers the critical factors that can achieve success in adopting MMC in social housing projects in Egypt. The aim of governmental support is to enhance the factors that can prompt the implementation of MMC by developing a series of activities. The SHMFF, as the main governmental entity providing and planning social housing projects, would be responsible for supporting the implementation of MMC in their projects. SHMFF would collaborate with SHC to offer financial incentives in order to encourage them to invest in MMC. The financial benefits would be conditional on adopting MMC to encourage the private sector and SHC to start investing in it. This is to mitigate the financial risks, addressing the costs, challenges, and barriers. The SHMFF will address the lack of knowledge and awareness of MMC by conducting media campaigns to introduce the advantages of MMC, including its social, cultural, and sustainability benefits.

Moreover, SHMFF will address the cultural and social aspects of the residents through collaborations with the local councils and housing authorities to develop housing policies that address the needs of the residents locally through MMC. The main aim is to consider the diversity of the residents between different regions in the country, which could be achieved by involving the residents in the local councils in the early design stages of social housing projects. Early consideration of the cultural, environmental, and social factors in design and implementation increases the success rates of MMC. On the other hand, adopting MMC helps achieve the government's sustainability and innovation goals

in accordance with the country's Egypt 2030 policy. SHMFF would work with housing authorities and SHC to set new housing policies that encourage the adoption of MMC in social housing projects to foster sustainability, performance, and innovation in them.

6.1.5. Social and Culture

The social and cultural pillar is aimed at preserving the socio-cultural identity of the residents in addition to the social and cultural challenges identified from the data analysis. Firstly, it addresses the cultural challenges identified in the qualitative analysis, including the tough mindsets of workers and resistance to change. These challenges are addressed by targeting younger generations of workers to learn and gain the required skills to adopt MMC. These aspects are interrelated with providing training facilities and training incentives from the SHMFF and education providers. It will help reduce the effect of the negative perception of prefabricated houses as previously documented, which would act as a barrier to MMC implementation and raise awareness and knowledge of MMC. Furthermore, the resistance to change is also addressed by requiring change management agents to assist in transitioning to MMC approaches from the traditional approach. This develops an interrelationship between the project managers, SHMFF, and SHC to manage the change from the senior management and decision-makers to the workers.

The socio-cultural factors of the residents are also considered. Designers must carefully consider these aspects during the design process with the residents. The involvement of the residents in the early design stage is crucial to the success of MMC adoption to ensure it satisfies the specific socio-cultural aspects of the design. It will also contribute to reducing the negative perception of MMC, increasing its knowledge among the residents, and increasing awareness of MMC technology. In addition, SHMFF and SHC ensure strong supervision in the manufacturing and assembly of the units to improve the quality of units and users' satisfaction to achieve successful adoption of MMC units.

6.1.6. Technology

The lack of technological readiness is the main factor in this pillar. To avoid resistance to implementing MMC, the framework considers gradual technology transfer for adopting MMC in social housing projects. The main activity is implementing BIM in social housing projects to overcome the coordination challenges between the factories and construction sites. This requires the full coordination between manufacturers, designers, and SHC to utilise BIM when adopting MMC in their projects. The lack of technology interrelates with the construction industry's capabilities, requiring strong project management skills to manage the technological adaptation within social housing projects.

6.1.7. Manufacturing Industry

The current manufacturing capabilities of Egypt and the improvement in the physical infrastructure are the main critical success factors. This pillar aims to benefit from the availability of precast factories and upgrade them to adopt MMC technology for social housing projects. This would be less expensive than establishing new factories; therefore, it would overcome the initial funding and high capital barriers for MMC adoption. Manufacturers and SHCs would be encouraged to invest in MMC through financial incentives that SHMFF could potentially provide to adopt MMC in social housing projects. As previously mentioned, governmental support is crucial to manufacturers and SHC to adopt and implement MMC through the financial benefits available by law to invest in innovation and sustainable approaches in social housing construction.

Benefiting from the improvement of the road infrastructure and the availability of industrial cities, the framework addresses this success factor by launching new social housing projects close to industrial cities to limit transportation issues. It will be more accessible to manufacturers and SHC to have manufacturing facilities close to construction sites to improve coordination and management of projects. Furthermore, the pillar considers the social and cultural factors in the manufacturing industry, represented by

poor quality control and a lack of coordination, by addressing the need for strong project management skills and leadership. Supervision and project management skills are essential to successful MMC implementation to minimise coordination issues arising from MMC's complex manufacturing and assembly requirements.

The framework provides an understanding of the specific nature of the Egyptian construction and housing sectors, where its main target is to integrate MMC systematically. To implement this framework, the activities must be executed sequentially to ensure a successful adoption process. Thus, the framework considered a multi-phase approach to achieve successful implementation by combining certain activities from the seven pillars. Table 4 illustrates the framework's implementation phases by presenting the activities in order of execution and the stakeholders involved in each activity.

Table 4. Implementation phases of the framework.

Phase	Activity	Stakeholders
Phase 1 Strategy implementation	Establish partnerships with the private sector to build social housing units.	• SHMFF • SHCs
	Provide technical education incentives to SHC.	• SHMFF • SHCs • Education providers
	Include MMC in social housing policies.	• SHMFF
	Provide financial incentives to the private sector and SHC implementing MMC.	• SHMFF
	Develop policies that consider cultural and social aspects of the residents, including diversity.	• SHMFF • Local housing authorities
Phase 2 Strategy implementation	Secure contracts with a large number of units.	• SHMFF • SHCs
	Launch new social housing projects close to current industrial cities.	• SHMFF • Local authorities
	Increase knowledge and awareness of MMC.	• SHMFF • Education providers
	Attract the younger generation of workers to learn MMC methods.	• SHCs • Education providers • SHMFF
	Ensure gradual technology transfer.	• Manufacturers • Private sector investors
Phase 3 Operational strategy	Design social housing units to be MMC-friendly.	• SHMFF • Architectural designers • Manufacturers
	Improve the architectural design of interiors and exteriors.	• Architectural designers • SHMFF
	Increase the variations and flexibility of unit designs.	• Architectural designers • SHMFF
	Ensure sustainability, health and safety, and cost efficiency through MMC in social housing.	• SHMFF • SHCs
	Increase the safety and privacy aspects of social housing units.	• Architectural designers • SHMFF

Table 4. *Cont.*

Phase	Activity	Stakeholders
Phase 4 Execution strategy	Employ available prefabrication manufacturing capabilities and modernise them.	• SHMFF • Manufacturers • SHCs
	Utilise BIM software from the design stage in social housing projects.	• SHCs • Architectural designers • Manufacturers
	Utilise the current precast factories to adopt MMC in social housing.	• SHMFF • Manufacturers • SHCs
	Provide strong project management and leadership.	• Local authorities • Project managers • SHCs
	Ensure robust supervision and monitoring locally.	• Local authorities • Project managers • SHCs

7. Phases of Implementation of the Framework

To ensure the successful implementation of the framework, it needed to be divided into a series of phases where each phase contains several activities to be performed by the relevant stakeholders. As shown in Table 3, the framework's activities are divided into four phases. The first phase is the strategy planning stage, where the main stakeholder involved is the SHMFF, the authority responsible for setting the policies and planning social housing projects. The SHMFF will work with SHC and local housing authorities to develop policies that encourage the adoption of MMC in social housing projects. SHMFF will need to establish partnerships with the private sector to build social housing units using MMC. The target of these partnerships is for the private sector to benefit from the financial incentives SHMFF could bring, according to Law 93 in 2018. These incentives include education incentives for the private sector to invest in technical education and training facilities to train unskilled workers to teach and learn the required MMC skills.

In phase 2, the strategy implementation is formulated by setting the next series of steps to achieve the goals of phase 1. Through Public–Private Partnerships (PPPs), the main target is to secure contracts with a large number of units to help absorb the high initial costs of MMC and reduce the cost of units. This could be achieved by implementing new social housing projects close to industrial zones, which could be coordinated between SHMFF and local authorities. Simultaneously, SHMFF will need to increase the knowledge and awareness of MMC, including its benefits and improvements it could bring to the construction sector and the housing sector as well. This will require collaboration between SHMFF, technical education providers, and SHC to prompt MMC adoption and implementation. Furthermore, manufacturers and the private sector will be working to ensure the gradual technology transfer of MMC to the manufacturing sector.

In phase 3, the SHMFF will collaborate with architectural designers to address the challenges of the current social housing sector. The design of social housing projects implemented under this framework must consider MMC approaches for their construction. Architectural designs would focus on reviving the Egyptian architectural heritage by benefiting from the standardisation nature of social housing units and the advantage of MMC technology that could introduce specific architectural styles relevant to the Egyptian heritage. This includes improvements to the architectural designs of the units to provide more flexibility and better interior and exterior designs. In addition, the safety and privacy factors require more focus from SHMFF and architectural designers, as they were the highest-rated factors from the quantitative analysis.

Moreover, in this phase, SHMFF and SHC need to ensure the sustainability and cost efficiency of the construction of social housing projects. Stakeholders should provide a more sustainable construction process by utilising more sustainable materials and reducing onsite work and construction waste, which MMC approaches can achieve. In addition, prompt environmental performance and energy efficiency in social housing units are some of the main drivers of adopting MMC.

The purpose of the fourth phase, the execution strategy, is to establish the manufacturing facilities for social housing projects and to start production. Collaboration between SHMFF, manufacturers, and SHC is required to explore how the current precast manufacturing facilities can be developed to employ MMC in social housing projects. SHC and manufacturers must identify the appropriate MMC method to ensure it meets their capabilities. In the beginning, panel systems or sub-assemblies could be adopted to manufacture specific components of the units that can be standardised. This ensures that it can be easily integrated within the current practices of the construction sector and could be taught to the current workforce. With the steady progress of adopting MMC in social housing, developing training facilities, and understanding MMC approaches, more complex prefabrication methods could be adopted, such as volumetric units that can be used as bathroom and kitchen pods with the goal of manufacturing fully functional housing units offsite.

Eventually, strong leadership skills and project management knowledge are required to adopt MMC successfully in social housing projects. This is necessary due to the complexity of the process and the large number of stakeholders involved; in addition, the need to satisfy the requirements of each stage provides adequate coordination between them. Moreover, during the execution of projects, robust supervision and monitoring are crucial for successful implementation by local authorities due to the social and cultural differences between various locations.

8. Conclusions

The literature has documented the benefits of MMC and offsite prefabrication to the construction industry. It has been sought after as a solution to the drawbacks of the construction industry, including poor quality, lack of sustainability, health and safety issues, etc. The aim of this research is to bring offsite prefabrication technology to the Egyptian housing sector. It has been proven in several studies that MMC brings improvements to the construction sector and that it has been adopted in many developed countries to increase the supply of decent housing for the least advantaged. However, transferring MMC technology requires exploring and identifying the critical success factors, challenges, and barriers to its implementation within the Egyptian context. This research examined the influencing factors to adopt MMC in Egypt's construction and housing sectors to recognise their impact on developing a framework for the successful adoption of MMC in social housing projects.

Upon identification of the influencing factors, the aim of the research was achieved by developing an adoption framework for the successful implementation of MMC in social housing projects. It was developed by understanding the main success factors contributing to MMC adoption in developed countries, how they can be exploited in the Egyptian context, the main challenges and barriers, and how they can be mitigated. The framework consists of seven pillars covering the main aspects of the successful adoption of MMC, which was discussed in detail in Chapter 6, including its implementation phases. It is presented as a series of activities to be performed by their relevant stakeholders simultaneously by considering the challenges that might arise during the implementation process.

The framework does not just transfer the prefabrication technology by importing it from developing countries. It develops an implementation strategy to integrate MMC innovation into the current construction practices in social housing projects where traditional construction is the only practice. Conventional construction has been proved in the research as insufficient to provide the needed supply of social housing in Egypt, where the shortage has kept increasing through the decades.

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References

1. CAPMAS. *Economic Census Egypt 2018*; Central Agency for Public Mobilization and Statistics: Cairo, Egypt, 2020. Available online: https://censusinfo.capmas.gov.eg/Metadata-en-v4.2/index.php/catalog/405/related_materials (accessed on 26 August 2024).
2. CAPMAS. *Egypt in Figures*; Central Agency for Public Mobilization and Statistics: Cairo, Egypt, 2022. Available online: https://www.arabdevelopmentportal.com/publication/egypt-figures-population-2022 (accessed on 26 August 2024).
3. Abdelwahed, M.; Hanafy, A. Overview of Social Housing Provision in Egypt 1. *J. Alex. Univ. Adm. Sci.* **2020**, *57*, 207–243.
4. Abdel-Rahman, H.M.; Elsayed, Y.M.; Abouelmagd, D. Assessing the Egyptian Public Housing Policies and Governance Modes. *Helwan. Edu. Eg-JAARS* **2020**, *1*, 13–30.
5. UN-Habitat. *Egypt Housing Strategy*; UN-Habitat: Nairobi, Kenya, 2020.
6. Ahmed, G. Residents' socio-cultural dissatisfaction in the two stages of public housing in Cairo, Egypt: What has changed in the third 'current' one? *Urban Des. Int.* **2012**, *17*, 159–177. Available online: https://search.ebscohost.com/login.aspx?direct=true&db=edswah&AN=000309048100002&site=eds-live (accessed on 10 May 2023). [CrossRef]
7. Marketline. Construction Industry Profile: Egypt, pp. 1–33. 2017. Available online: https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=128135402&site=eds-live (accessed on 10 May 2023).
8. Marzouk, M.; Hosny, I. Modelling housing supply and demand using system dynamics. *Hous. Care Support* **2016**, *19*, 64–80. [CrossRef]
9. IHS Global Inc. Country/Territory Report—Egypt. pp. 1–58. 2020. Available online: https://search.ebscohost.com/login.aspx?direct=true&db=buh&AN=142075956&site=eds-live (accessed on 10 May 2023).
10. Egypt Economic Development Conference. In Proceedings of the Egypt Economic Development Conference, Sharm El-Sheikh, Egypt, 13–15 March 2015.
11. Schwab, K. The Global Competitiveness Report 2017–2018. 2017. Available online: http://www3.weforum.org/docs/GCR2017-2018/05FullReport/TheGlobalCompetitivenessReport2017%E2%80%932018.pdf (accessed on 10 May 2023).
12. Bah, E.M.; Faye, I.; Geh, Z.F. *Housing Market Dynamics in Africa*, 1st ed.; Palgrave Macmillan UK: London, UK, 2018. [CrossRef]
13. MPED. Ministry of Planning and Economic Development Reviews the Objectives of Egypt's Manufacturing Industry Sector in the FY 21/2022 Plan. 2021. Available online: https://mped.gov.eg/singlenews?id=644&lang=en (accessed on 10 May 2023).
14. Abd El-Razek, M.E.; Bassioni, H.A.; Mobarak, A.M. Causes of delay in building construction projects in egypt. *J. Constr. Eng. Manag.* **2008**, *134*, 831–841. [CrossRef]
15. El-Safty, A.; Elsafty, A.; Malek, M. Construction Safety and Occupational Health Education in Egypt, the EU and US Firms. *Open J. Civ. Eng.* **2012**, 174–182. [CrossRef]
16. El-Kabbany, M. Alternative Building Materials and Components for Affordable Housing in Egypt towards Improved Competitiveness of Modern Earth Construction. Master's Thesis, Ain Shams University, Cairo, Egypt, University of Stuttgart, Stuttgart, Germany, 2013.
17. Marzouk; El-Rasas. Analysing delay causes in Egyptian construction projects. *J. Adv. Res.* **2014**, *5*, 49–55. [CrossRef] [PubMed]
18. Daoud, A.O.; Othman AA, E.; Ebohon, O.J.; Bayyati, A. Analysis of Factors Affecting Construction and Demolition Waste Reduction in Egypt. *Int. J. Constr. Manag.* **2021**, *23*, 1395–1404. [CrossRef]
19. Dolage DA, R.; Chan, P. Productivity in construction-A critical review of research. *Eng. J. Inst. Eng. Sri Lanka* **2013**, *46*, 31–42. [CrossRef]
20. Bertram, N.; Fuchs, S.; Mischke, J.; Palter, R.; Strube, G.; Woetzel, J. Modular Construction: From Projects to Products, McKinsey Insights, pp. N.PAG. 2019. Available online: https://lsbu.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=edb&AN=137075653&site=eds-live (accessed on 10 May 2023).
21. Ofori-Kuragu, J.; Osei-Kyei, R.; Wanigarathna, N. Offsite construction Methods—What we learned from the UK housing sector. *Infrastructures* **2022**, *7*, 164. [CrossRef]

22. Saunders MN, K.; Lewis, P.; Thornhill, A. *Research Methods for Business Students*, 9th ed.; Pearson Education Limited: Harlow, UK, 2023.
23. De Vaus, D.A. *Surveys in Social Research*, 6th ed.; Allen & Unwin: Sydney, VIC, Australia, 2014; Available online: https://www.taylorfrancis.com/books/mono/10.4324/9780203519196/surveys-social-research-david-de-vaus-david-de-vaus (accessed on 10 May 2023).
24. Shibani, A.; Mahadel, O.; Hassan, D.; Agha, A.; Saidani, M. Causes of time overruns in the construction industry in Egypt. *Int. Res. J. Mod. Eng. Technol. Sci.* **2021**, *3*, 510–531.
25. Fahmi, W.; Sutton, K. Greater Cairo's housing crisis: Contested spaces from inner city areas to new communities. *Cities* **2008**, *25*, 277–297. [CrossRef]
26. Eldefrawi, S. Community and neighbourhood in Egyptian context, case formal and informal settlements—Cairo. *Int. J. Soc. Sci. Humanit.* **2015**, *5*, 281–286. [CrossRef]
27. Lines, B.C.; Sullivan, K.T.; Smithwick, J.B.; Mischung, J. Overcoming resistance to change in engineering and construction: Change management factors for owner organizations. *Int. J. Proj. Manag.* **2015**, *33*, 1170–1179. [CrossRef]