CRITICAL SUCCESS FACTORS, BARRIERS AND CHALLENGES FOR ADOPTING OFFSITE PREFABRICATION: A SYSTEMATIC LITERATURE REVIEW

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Egypt suffers from huge deficit in low-income housing despite several mitigation attempts. The housing deficit has reached 3.5 million units in 2017 due to several issues including high population increase rate, overcrowding, slum dwellings, poor housing stock and poor performance of construction sector. In order to address these challenges, offsite prefabrication has been proffered as an innovative solution to provide decent housing to the least advantaged households. This paper presents the findings of a systematic review of selected literature on adopting offsite prefabrication in several developing and developed countries. The review concluded that the housing deficit would not be reduced through conventional construction methods; hence, a new construction approach is needed that integrates manufacturing with construction. On the other hand, the critical success factors for successful adoption of offsite prefabrication include governmental support, adopting new building codes, integration of private sector, industrial capabilities and social and cultural factors. It is concluded that offsite prefabrication can leverage low-income houses delivery in addition to improving the performance of the Egyptian construction sector.

Keywords: Egypt, housing, offsite prefabrication, success factors

INTRODUCTION

Providing low-income housing to the least advantaged households has always been a major challenge to housing authorities especially in developing countries. Several factors are associated with this challenge including the rapid increase in population in addition to the deterioration of the current housing stock. Other factors include low quality, insufficient funding, delivery duration, governmental policies and legislations, sustainability, occupiers' satisfaction and social and cultural factors. Egypt as developing country and one of the largest countries in the world in terms of population, ranking 14 in the world population, suffers from significant housing crisis where traditional methods are insufficient to fill the deficit of low-income housing. However, far too little attention has been paid to implement innovative construction methods to increase the housing supply rate rather than conducting research on the challenges and deficits in housing supply.

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On the other hand, improvements to the construction industry have been under continuous research and development. Off-site Prefabrication (OSP) has always been considered as an innovative method of construction by taking the advantages of improved factory conditions to the building sites. Transition to OSP has been the aim of developed countries to improve and speed up the delivery of low-income and social housing projects. The adoption of OSP has passed through different stages of development to successfully implement it in the construction industry. This review intends to highlight the critical success factors, barriers and challenges that will be the foundation of adoption framework for offsite prefabrication in Egyptian low-income housing projects.

RESEARCH METHOD

An extensive review of the literature on two main study areas has been conducted. Egyptian housing supply and demand and Egyptian construction industry as the first study area. The chronological development of adopting offsite prefabrication in housing projects in a selection of developed countries, United Kingdom and United States of America, in addition to developing countries in Middle East and North Africa (MENA) region, Saudi Arabia and Algeria as the second study area. The review of the first study area has been performed in order to identify the critical factors affecting the supply of low-income housing units including the policies, rate of supply and demand and the challenges facing them. The second study area is aimed to provide the lessons learned countries that have a long history of utilizing offsite prefabrication in housing projects. it will provide the factors associated with the adoption process as well as the challenges and barriers to it. The combination of factors from those two study areas will be the foundation of implementation framework for successful adoption of prefabrication in the Egyptian housing projects.

The literature has been reviewed systematically through selecting the relevant peer-reviewed journal articles, conference papers, governmental reports and market research reports. A preliminary internet research has been conducted using keywords "offsite + prefabrication + housing" to identify the relevant articles and reports. Several online libraries and construction management related journals were also searched in order to provide an overview of the research topic. Critical assessment has been performed to the selected resources to narrow down the articles related to the study. The selected resources have been critically analysed and synthesised in order to identify the patterns and key factors relevant to the research in addition to identify the gaps in the body of knowledge.

Housing in Egypt

Egypt has always suffered from shortage of social and low-income housing supply especially in Cairo, the capital. Since 1950s the government is the main supplier of low-income housing in Egypt. It established housing institutions such as Housing Fund and General Organization for Building and Housing Co-operatives as well as establishing construction companies. In addition, the Ministry of Housing was responsible for the planning, design and management of public housing projects. From the late 1990s to mid-2000s, low-income housing projects were concentrated into two main mega projects, "Youth" and "Future" housing projects. "Youth" project started in 1996 and supplied a total of 84433 units through the period until 2004. On the other hand, "Future" project supplied 15636 units from 1998 to 2001 (New Urban Communities Authority, 2020). During the period from 2005-2011 the National Housing project was initiated to provide 500,000 units with annual supply of 85000

units. According to CAPMAS (2019), the annual supply of economic and middle level housing units had been less than 100,000 units, except in 2015, by the public sector.

On the other hand, with average 2% annual increase in population the gap between supply and demand in housing especially for the low-income level keeps increasing (IHS Global, 2020). According to EEDC (2015), Egypt requires more than 550,000 houses annually between new households and the replacement of slum dwellings. The backlog in housing resulted from this gap reached around three million units, as announced by the government, aiming to supply 300,000 units annually for new households as well as around 254,000 units to overcome the backlog from the past. Besides, the current low-income housing conditions have been severely deteriorated due to lack of maintenance and poverty. This generated slum dwellings need to be replaced although most of the population cannot afford buying new houses where the houses price to income ratio has reached 18.4 years (EEDC, 2015). In 2014, the Social Housing Program was announced by the government to build one million low-income houses in collaboration with the World Bank who is lending the government $500 million. However, only 296,022 has been built by the end of year 2019 with approximate annual supply of 59,000 units (Ministry of Housing, Utilities and Urban Communities, 2017). Furthermore, the majority of the private sector's housing developments are targeted to the high-income and luxury market 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 permit leading to the increase of improper housing which is most of the time considered unsafe (Marzouk and Hosny, 2016).

Construction industry

The dominant construction method in Egypt is the traditional method of concrete and brick. According to Marketline (2017), the construction materials market is concentrated on cement (concrete), steel, aluminium and bricks with few substitutes available. The industry has serious issues in the workforce skills and productivity. Initially, the majority of the workforce comes from the rural areas and villagers to cities where most of the construction work is conducted; therefore, most of them lack proper training. There is only one big construction company in Egypt that has a proper training system while other companies on governmentally educated labour which is poor and insufficient (EL-Gohary and Aziz, 2014). There are concerns about quality in construction projects where the industry is categorized as poor quality. The main quality issues are lack of technological background, lack of training and experience and the industry officials' dereliction in establishing specific rules and classifications of contractors and defining their responsibilities (Abdel-Razek, 1998). Moreover, projects delays have been one of the main concerns in the Egyptian construction. The main causes of delays are shortage of construction materials, cost related issues, shortage of labour and low productivity (Marzouk and El-Rasas, 2014). Moreover, Abdel-razek (1998) argues that quality control measures adopted in Egypt have been inverted from the techniques developed in the West and Far East without any adaptation to the characteristics of the Egyptian industry leading to poor application of quality control measures and failures in ensuring high-quality end products. These issues have serious impact on the quality of buildings that hardly can be improved by the traditional methods. In terms of health and safety, a comparative study between the performance of Egyptian and US companies showed that the Egyptian's suffered from incidents and injuries almost 7 times higher than the US's

(El-Safty *et al.,* 2012). The research discovered serious issues with the industry's health and safety performance such as lack of training and orientation for workers, lack of medical facilities onsite and lack of general awareness of health and safety procedure even for personal protective equipment.

Chronological Development of OSP

Developed countries

United Kingdom

According to Gibb (1999), prefabrication origins goes back to the twelfth century where it was mentioned in several studies concerned about housing construction, it is the era that witnessed the implementation of industrial methods in construction. The interwar period witnessed the major development of prefabricated houses especially the 1920s houses (Powell, 1996). However, it faced public opposition and technical failures which resulted in limited supply (Hughes, 2002). Other manufacturers proposed different structural materials such as pre-cast concrete, cast iron and shredded wood and concrete. The drivers which influenced the development and adoption of prefabrication as stated by Hashemi (2013) are the World War, Modern architecture in addition to massive housing programmes initiated by housing authorities that had been larger than the traditional methods builders' capabilities, whether resources or skilled labour.

After the Second World War, the demand on housing increased facilitated by houses being destroyed or uninhabitable, slum clearance and increase of population. Therefore, the government lead by Winston Churchill declared the production of 500,000 temporary houses as an objective (Hashemi, 2013). However, only 156,623 prefabricated houses were delivered in the post-war period instead of the 500,000 that had been announced consisting of only four types of single storey houses. That was most likely due to the shortage of mechanical plant and factories in the post-World War era resulting in shortage of fulfilling the required capacity. These houses had several technical failures such as thermal and sound performance, condensation and quality issues. In addition, they were economically infeasible when compared to traditional houses despite the governmental support (O'Neill and Organ, 2016).

The period from 1950s to 1980s witnessed significant changes to the methods of construction to be more industrialised. This enthusiasm to industrial buildings and non-traditional methods was driven by the special post-war conditions and huge reconstruction demand especially in housing (Hasehmi, 2013). Consequently, volumetric construction methods were employed in this era that included manufacturing of building in the form of boxes to be assembled onsite prefabricated by light-weight frames from steel, timber or concrete. Due to several failures such as Ronan Point collapse, the government introduced tighter design codes and established governmental bodies such as National Building Agency (NBA) that encouraged the use of system buildings in addition to emphasising on research and development of modern methods of construction (BRE, 2002).

Offsite prefabrication has been remarkably encouraged in the 1990s to the present time by governmental research/reports which resulted in the public starting once again to reconsider alternative modern construction techniques (BRE, 2002). These initiatives include the Latham Report 'Constructing the Team' in 1994, the Egan Report 'Rethinking Construction' in 1998, the Barker Review in 2003. They encouraged the use of offsite prefabrication in constructing high quality houses required in the UK alongside with a policy promoting this type of construction. In

order to bypass the negative public perception of offsite prefabrication approaches, the term MMC 'Modern Methods of Construction' had been introduced to describe non-traditional construction methods instead of prefabricated systems. MMC has been supported by political, economic, environmental factors to improve the image of the industry and increase productivity (O'Neill and Organ, 2016). This governmental support encouraged the private sector to invest in MMC alongside with the tightened building regulations and planning by emphasising on sustainability and environmental performance.

United States

Following the World War II, house builders employed industrialized techniques in traditional housing system such as assembly-line process. The development of prefabricated systems was mainly in the 1940s through inventing wood-stud panels system followed by the development of trailers by an aircraft company to produce the first designed trailer as a house (O'brien *et al.,* 2000). In 1974, mobile homes were granted official recognition through Department of Housing and Urban Development (HUD) by obtaining congressional approval to implement a construction code. Nevertheless, mobile homes were ceased from production afterwards as a result of shifting towards manufactured homes by amending the construction codes. Modular houses started to emerge in the 1980s and 1990s gaining the consumers' confidence as it developed through the years (O'brien *et al.,* 2000). OSP currently has developed and became more reliable in the US construction industry driven by the advance in technological innovations to build high quality and sustainable buildings. The private sector is the major employer of manufactured houses by 66% driven being almost 50% cheaper than traditionally built houses (MHI, 2018). However, being cheaper does not mean that they are lesser quality as HUD revised the regulatory codes to ensure its efficiency in terms of design, quality, energy efficiency and environmental performance.

OSP in MENA region

Saudi Arabia

OSP is considered to have very limited adoption in residential projects which almost negligible. The OSP techniques implemented are mainly prefabricated concrete panels for bridges and overpasses used in highway and road projects, wall and façade panels for high rise projects and temporary structures such as site offices. However, these panels are not manufactured in permanent factories, they are casted in site. Thus, those workers involved in this process were untrained on production process and mass production techniques (Aburas, 2011).

Recently, few companies in Saudi Arabia are trying to implement affordable prefabricated housing such as Abdul Latif Jameel by introducing uniquely designed houses constructed from pre-manufactured components (Abdul Latif Jameel, 2018). However, there are no accurate figures about how much these houses are implemented which are more likely to be still in its trial versions. The uptake of OSP is limited due to several barriers. Firstly, the lack of legislations and governmental willingness for innovative methods in construction. Moreover, the reliance on traditional concrete and steel which acts as a barrier for transport and handling of prefabricated components due to its heavy weight. Eventually, the general perception on prefabricated houses is low quality and temporary houses (Aburas, 2011).

Algeria

Starting by the National Development Plan (1974-1977), several national companies were allowed to import industrialised building systems as thought by the government to be an absolute solution to the housing shortage. In order to control and organize the industrialisation process, the government established the Ministry of Urban Planning, Construction and Housing (MUCH) in 1977, which was responsible for setting the organizational framework of housing policies and urban development. The (MUCH) initiated an urban development policy (ZHUN) to provide mass-produced new houses using industrialised systems (Behloul, 1991). ZHUN policy included the implementation of large-scale urban developments created as standardised five-storey flat blocks by employing European architects and building companies. Foreign companies had imported heavy prefabrication systems in order to provide standardised dwellings associated with its public amenities to create urban communities by using mainly French 'Grand Ensemble' designs. However, these developments lacked success to satisfy the housing requirements for the Algerians for several reasons (Hadjri, 1993).

The houses were designed according to European standards and norms that did not meet the Algerians social identity. In addition, building materials utilized were not adequate for the hot climate conditions resulting in poor thermal and waterproofing insulation. As a result, habitants started to make changes and modifications to their houses in order to meet their social and economic needs such as privacy and the need for more space (Hadjri, 1993). Consequently, the ministry decided to stop the importation of heavy prefabricated systems and choose another alternative to provide houses. The ministry decided to develop local building companies that utilizes smaller industrial units of prefabrication techniques such as the panel system, framework construction or hybrid systems (Behloul, 1991). Eventually, the ZHUN developments failed to fulfil its targets as a solution to housing shortage due to lack of appropriate utilization of prefabrication techniques to the local construction industry in addition to economic difficulties.

DISCUSSION

Adopting OSP in the construction industry in developed countries has not started recently, it took decades to have its current influence on the industry where it started in the United Kingdom and the United States in the 1800s. However, OSP implementation can be considered a failure rather than successful in the early stages as it was mainly based on trial and error. It has been implemented driven by industrial and environmental factors as well as the increased demand resulting from increased population, where the Industrial Revolution in the 1800s in the UK and USA had its effect on the construction industry. However, in this early stage the aim was to introduce industrial method to the construction industry without considering other factors affecting home building such as socio-cultural factors, training and skills development.

The post-WWII era could be considered the renaissance era for OSP in developed countries. Different methods and types of prefabricated houses emerged as a faster solution to provide decent housing. It was mainly driven by massive demand for housing after WWII, shortage in trained labour and materials in addition to political aim to enhance industrialization. However, these factors were not enough to succeed despite governmental support. Lack of building regulations and codes in the USA and shortage in manufacturing capabilities in the UK were all factors that hindered

successful implementation of OSP alongside with high initial cost and negative public perception of prefabricated houses in all these countries.

It can be noted that there are critical factors that lead to the current development and the increased share of OSP in the housing market. Governmental continuous insistence on implementing and developing OSP in the housing sector that can be witnessed through establishing governmental bodies such as the National Building Agency (NBA) and Building Research Establishment (BRE) in the UK and Manufactured Housing Institute in the USA that produced research and initiatives to encourage alternative construction techniques (BRE 2002, MHI 2018). Research alongside governmental initiatives have a significant role in adopting OSP emphasising on its technical, environmental and economic feasibility with respect to traditional construction methods.

Research in developing countries is very limited on OSP when compared to developed countries that mainly focus on improving the traditional construction methods. Nevertheless, research/initiatives did not focus on specific challenges such as how to improve the negative public perception of prefabricated houses that act as one of the major challenges to OSP globally. In addition to how to adopt different OSP methods to the culture to be implemented in as well as how to avoid the cultural resistance to change either from the public construction professionals. In the Algerian model in the 1970s, the techniques imported from Europe did not satisfy the socio-cultural requirements of the occupiers due to utilizing it with its original design and standards that does not meet the Middle Eastern conservative culture. It was considered unsuccessful resulting in ceasing importation and returning to the traditional methods.

Another form of governmental support to OSP is developing building codes and legislations that encourage adopting innovative and non-traditional methods of construction. This was backed by the disadvantages of traditional construction methods such as poor quality, shortage of skilled labour, health and safety issues and the impact of increased waste on the environment. Imposing new laws and building regulations is critical to successfully adopt OSP in developing countries. The Ronan Point collapse incident was one of the main reasons that UK introduced tighter design codes to eliminate such incidents. Laws and legislations will also increase confidence in OSP either to the public or construction professional. However, it is not easy to introduce new laws or building codes, so implementing OSP should comply with the existing building regulations to be adopted more smoothly in the current practices. To adopt OSP in a construction industry, the adoption framework should include how building codes to be modified to support its successful adoption.

One of the major challenges of implementing OSP is the high initial cost to establish the manufacturing facility. In addition to factories overhead cost is fixed despite the production which will be unfeasible if the produced quantities are small. In developed countries, governments tried to overcome this economic challenge by involving the private sector in the housing production. In addition to providing local authorities as well as private sector with subsidies to promote OSP to cover the initial cost. In developing countries, governments usually take full responsibility to finance low-income and affordable housing, thus, they look for the most cost-effective building solutions to build more houses. Therefore, there should be a methodological framework to integrate the private sector in emerging and developing countries in order to increase the financial capabilities to accommodate more innovative construction methods in housing projects. In order to successfully implement OSP,

the high initial cost should be absorbed in such a way that does not increase the overall building cost of housing projects.

Having an industrial and manufacturing capabilities can be a critical success factor to adopt OSP in developing countries. In the early stages to mass-produce prefabricated houses developed countries utilized its manufacturing facilities to create affordable solutions to the construction industry. However, there is no significant analysis in the literature of how to utilize the available manufacturing abilities to accommodate OSP techniques in housing projects. Although it is dependent on the techniques to be implemented, to develop a framework for utilizing the available manufacturing capabilities including training the workforce. Precast concrete factories have been in business in Egypt from long ago, thus, it can be the cornerstone of a comprehensive offsite solution to mass-produce low-income housing units by developing this industry with the latest prefabrication technologies.

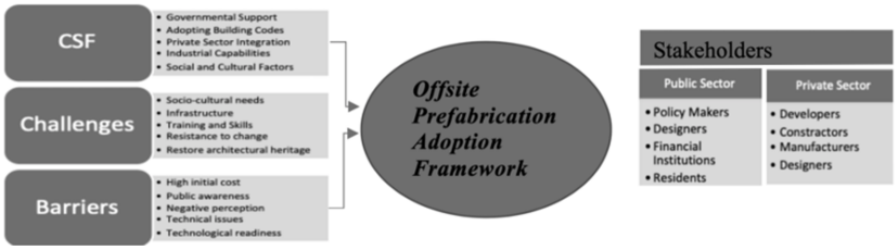
In the literature there were no emphasis on the social and cultural aspects with respect to adopting OSP. Although each country, UK and USA, implemented OSP according to its economic, political and manufacturing aspects, the cultural aspect was not analysed critically. By contrast, in Algeria the cultural and social aspect was one of the major factors that caused implementing prefabrication in housing to fail and cease to exist. The Egyptian cultural and social fabric suffers from complex issues including high unemployment, high poverty, religion conservative, family correlations, etc. In addition to the rich architectural heritage that is almost lost due to lack of maintenance and economic constraints. The framework to adopt OSP in Egyptian housing project must address these factors as it is essential to its success. Despite this, it is not only the occupiers social and cultural aspects that need to be considered, also the construction professionals and workers as well. The cultural norms and manners to be also considered in developing OSP adoption framework in order to integrate in the current construction practices.

One major issue in Egypt's low-income housing projects research that it is concerned about the drawbacks of the current practices rather than finding innovative delivery methods. Research has consistently been analysing the current drawbacks and problems associated with traditional construction methods in terms of quality, sustainability, delays and health and safety. With respect to latest governmental reports and rate of housing delivery, it can be proven that the current practices are insufficient to supply the needed number of units. Prefabrication has been widely researched and proffered as potential solution to increase supply of standardized housing units alongside its noted benefits such as cost reduction and quality improvement. However, in order to adopt OSP an adoption framework must be developed taking into consideration the critical factors affecting its adoption with respect to the country's specific conditions.

In order to successfully adopt OSP in housing projects, it must be integrated with the current practice to overcome potential barriers and challenges. These challenges and barriers alongside success factors identified from the lessons learned from developed countries that have been widely implementing OSP in their projects needs to be articulated with the economic, social, cultural, and technical capabilities and needs of the country to be implemented within. These critical success factors, challenges and barriers to be associated with the adoption framework of OSP are summarised in Figure 1. These factors are developed from the analysis of the literature within the context of Egypt which could be adopted to other developing countries. It includes

the main stakeholders involved in OSP adoption process who have significant roles to successfully implement the framework.

Figure 1: critical success factors, barriers and challenges to adopt OSP



CONCLUSION

The purpose of the current study was to determine the major issues in the Egyptian low-income housing sector in order to develop a framework for adopting OSP in housing projects. To do so, systematic analysis of the literature on housing supply and construction industry has been done to identify the current challenges, barriers and factors affecting low-income housing provision. On the other hand, the chronological development of OSP adoption in several countries has been analysed to determine the critical success factors, hindrances and lessons learned. The analysis was used to identify the critical success factors and challenges that need to be considered in developing OSP adoption framework including the stakeholders to be involved.

The study has shown that in order to develop a successful framework it is essential to have an in-depth analysis of the country's economic, social and cultural factors as well as the manufacturing capabilities not only the construction industry. The study highlighted the major challenges and barriers that can hinder OSP implementation and could lead to failures and prevention. The most obvious finding to emerge from this study is that there is potential to implement OSP application in the housing sector in Egypt. The improved quality, speed of delivery and mass production of housing units are all documented benefits of OSP that the housing sector in Egypt needs. Egypt has the manufacturing capabilities, infrastructure and market size that will act as factors of success. This study is considered as the base of future research on implementing OSP methods in Egypt or other another developing country. Further study and in-depth analysis are required to determine the specific method to be implemented and developed.

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