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STRATEGIC MANAGEMENT OF MODERN MANUFACTURING METHODS BASED ON PREFABRICATED SMART MATERIALS

Hasan Jabur[1], Mohamma dreza Bemanian[2], Mansoor Yeganeh[3]
[1,2,3]Department of Architectural Engineering, Faculty of Art and Architecture, Tarbiat Modares University, Tehran
[1]Email: Hassan.alaameri@gmail.com
[2]Email bemanian@modares.ac.ir
[3]Email yeganeh@modares.ac.ir

Abstract
Buildings and their lives have changed dramatically over the past two decades in line with technology. Innovative construction, moving to buildings with higher efficiency and better economic efficiency and environmentally friendly is essential. The use of smart building materials in today's buildings and timely response to changes will increase durability and life in buildings. The development of new materials has led to the reform of design and construction infrastructure, and in the meantime, intelligent materials have attracted the attention of researchers more than before, because these materials facilitate the process of rational and planned efficiency and change the characteristics of They have different needs and therefore intelligent materials can be considered as tools for designing buildings that are exposed to non-intermittent conditions. Today, in line with new developments, architects and designers are looking at smart materials and technology to solve long-term problems in building design. We are now on the verge of the next generation of buildings, buildings that have a completely ecological behavior and are able to react to direct and indirect changes around them by adapting to the compatible materials and performance of new technology, and to adapt to the right conditions. Give. Qard smart materials are adjusting to the growing global demand for expensive energy sources and raw materials. Intelligent architecture is a new approach to the future of construction in the world. Buildings that are able to adapt to indoor and outdoor conditions, so in this article, the introduction of smart materials and their performance and, more importantly, how to use and behave in construction projects is the main goal. May the knowledge of smart materials in a practical way encourage our architects to use these materials; the most important advantage is the optimization and intelligent management of energy.

Keywords: Strategic management, modern construction methods, prefabricated smart materials

Introduction

The existence of smart buildings in the new world is inevitable. A smart building is a building that has the ability to meet the needs of its users. The goals achieved by building a smart building encompass almost all aspects of human life. Productivity, high efficiency, energy storage, comfort and longevity of the building are examples of these types of goals that can be achieved by building smart mirrors. If a work can adapt to its possibilities and limitations at any time according to its needs, it can operate optimally with the best economic return. The best example of this flow is nature itself, in which living things adapt themselves to the environment in real time, and meet their needs. This primarily requires full awareness of the effects of environmental conditions and data. . In the last decade, with the emergence of new

technologies as well as advances in materials and other sciences, the ground for this has been provided, which can be called intelligent architecture.

Development in the field of materials, products and innovative construction methods is necessary to move towards buildings with higher efficiency, better economic efficiency and environmentally friendly. We are now on the threshold of the next generation of buildings, buildings with various degrees of new Hi technology - Tech that have completely ecological behavior that are able to intelligently use compatible materials and proper performance to react to direct and indirect changes around them and adapt to the right conditions. It is hoped that recognizing smart materials in a practical way will encourage our architects to use these materials, the most important advantage of which is energy optimization and intelligent management. In our time, the growing population and urban life along with the excessive consumption of energy is a major problem in nature conservation. Foresight and foresight have always been the focus of engineers and researchers who research and produce tools for future use. Reviewing the history of architecture of the last century in the field of futurism, we will see that this future is generally made of materials and technologies. Smart materials are the building materials of the future. Give. With the supply of smart materials, new capabilities and facilities will be provided to engineers and designers. These materials can improve the design and construction methods of buildings. Intelligence, and in particular the use of intelligent materials that respond to environmental issues, saves and useful life of the building, etc. The research is a descriptive analysis and data collection method is based on library studies. The most important findings and conclusions in this study are that smart materials have almost unstable power. They can change in response to their environment so that non-intelligent natural materials are able to make a positive difference in construction architecture and lifestyle.

The ancient discipline of architecture which designs and builds constructions especially for the accommodation of human activities has received significant conceptual extension in the past few years by the new attribute “smart.” Semantically connected to notions like context awareness, environmental sensitivity, structural responsiveness and adaptivity, active building, the comprehensive term “Smart Architecture” indicates a new level in design and construction related to intelligent information, and communication technologies[17]

A second main driver for the rapid evolution of smart solutions in the construction sector is the necessity to react to increasingly volatile conditions in the physical and social environment [16].Climate change poses new demands in regards to building physics and facility management. Resource efficiency and sustainability have emerged as new target criteria in (i) design, (ii) construction, and (iii) facility operations over the past decades, implying a close monitoring of energy and material consumption [8].Societal and demographic changes in turn dictate new life and work patterns, new demands of usage and occupancy, on which constructors, real estate developers, and operators need to respond with flexible and adaptable built structures [2]

The key benefit of smart or cybernetic systems arises from their capacity to provide appropriate communication and feedback structures which are able (a) to sense fast-changing conditions of the spatial environments and (b) to trigger and control their adequate response [6].This has resulted in key applications, for example, for energy monitoring and climate control, home surveillance and security, production automation and logistics, etc. The smartness of the

majority of the established solutions, however, unfolds on the level of technical appliances. Conceived and produced independently of the buildings' design and usage program, smart components are merely attached or applied as (retro)fittings to the basic spatial and structural components [12].

Few solutions exist in architecture and civil engineering which understand smartness as an inherent, integrated property of physical structures and components. This paper therefore puts focus on solutions and approaches that go beyond the appliance level. It exclusively uses the term smart architecture for building structures or components in which smartness is deeply implemented on the material structure level, that is, materials having either actuatoric or sensoria elements which enable the active and fast control of architectural key target parameters such as shape, visual appearance, or load bearing capacities.

Aims and motivation

As the use of modular buildings continues to rise, Evolution has experienced increased interest in Construction Management for the delivery of projects using modular buildings, with clients keen to understand how they can benefit from opting for modern methods of construction. [16]

Construction Management and Modern Methods of Construction are a perfect combination for anyone considering opportunities to deliver projects quickly and effectively whilst enhancing sustainability credentials. [22]

Construction management is a professional service that can be used to procure the delivery of a construction project as an alternative to D&B or Traditional procurement routes.

Construction management is often utilized by clients who have been let down by their existing provider. The client appoints a CM who takes over delivery of the project, acting on the client's behalf. Because the CM is appointed by the client and directly manages the trade contractors, the client has confidence that their best interests are protected. [15]

The CM's mandate is to collaborate with all parties to ensure a project is delivered at, or under, budget and achieves the required quality standard.

The prefabrication of building components is believed to have begun in the early 20th century. However, there have also been examples of previous use, such as the construction of the first iron bridge in the United Kingdom in 1779. The most significant push for OSM in the housing sector is said to have started after the First and Second World Wars, with the need for new buildings and reconstructions of those that were destroyed during the wars being the primary reasons [2]. Since then, other factors that have contributed to the push include skills shortage, quality enhancement, development in building regulations, sustainability, and environmental performance, and accuracy in buildings.

The construction industry has always been associated with the shortage of skills, which in turn has had an adverse impact on quality and pace of projects [11]. For this reason, there has been an increased need for modern methods of construction, where much of the construction process is carried out in a factory-controlled environment, thus reducing the requirement for skills on-site. According to Kamar et al., (2011) [3] the off-site production of building components enhances quality and helps in reducing the risks attributed to on-site quality management. Kamar and his colleagues observed that, though quality management is still critical on the construction site, it could be improved by having some of the site-based work performed off-site.

Although the situation regarding the reduction of quality is difficult to measure, the construction sector has on various occasions suffered from quality assurance challenges. However, as Rahman (2013) [12] pointed out, the current problem relating to quality is centred on improvement rather than assurance. The sector has always sought to enhance the quality of structure through modern technologies and approaches, while at the same time ensuring that productivity and sustainability are improved. In addition, the changes in customer expectations, especially in the housing industry, have heightened the need for continuous enhancement of quality [13]. For this reason, MMC has been viewed as an efficient solution to the quality problems associated with the traditional methods of construction.

For many years, the building regulations and related frameworks have been evolving at an alarming rate not only in the housing but also in other parts of the word [13]. As a result, there has been a growing need for increased adoption of SMMMC in the construction industry. For instance, the need for a threshold performance concerning thermal and sound insulation and energy consumption requires a construction method that is measurable and predictable. Furthermore, the possibility of performance evaluation after the completion of building places a much more significant need for a reliable and verifiable method than it was previously required [4]. Therefore, the use of off-site manufacturing methods is seen as a better way of achieving reliability and compliance with the regulations than the conventional site-based techniques.

The increased attention to the environmental impact of construction processes has also enhanced the need for sustainability of structures and construction methods (Lehmann, 2013). In this case, the application of MMC using off-site production, efficient components, and supply chain management is seen as one of the best approaches that can be used to reduce wastage and the associated environmental impact. As Nadim and Goulding, (2010) [13] argue, the quality control mechanisms employed in SMMMC can enhance airtightness, thus improving the thermal performance of the structure. The study observed that off-site manufacturing plays a critical role in reducing the environmental disturbances around the construction sites [13].

Panelized

To accelerate fabrication and decrease costs, PCBs are manufactured on panels; however, these panels have a direct effect on manufacturing costs. The more panels required to produce the desired quantity of PCBs, the higher the cost of manufacturing. To reduce the number of panels required, it is important to ensure space is used efficiently within the panel layout. The Fab Panelization Tool in OrCAD PCB Designer Professional will allow you to easily optimize your manufacturing panels. Features such as mirroring, board rotation, automatic array creation, and family panel support, improve the panel layout which reduce the number of panels required and decrease your manufacturing costs.

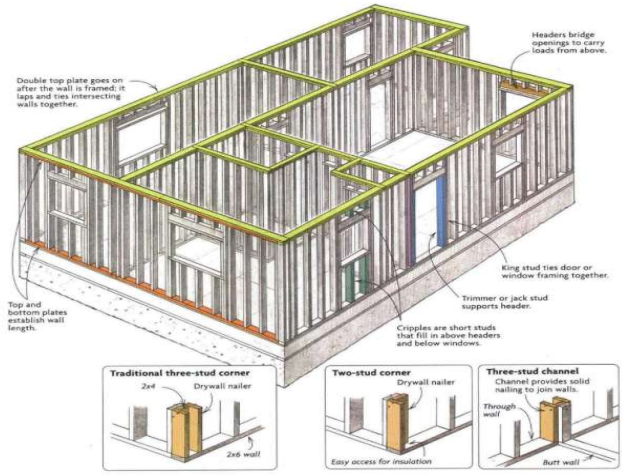

Fig 1. Panelized Wall

Sub-assemblies & Component

Any part of a building made in a factory and brought to the construction site can be classed as a sub-assembly, which forms part of a component system. Sub-assemblies can be as small as locks and handles for the doors, or they can be larger components such as pre-assembled roof trusses. These are individual housing elements, such as pre-assembled roofs and pre-fabricated chimney stacks, designed to be added to existing structures. Sub-assemblies and components can be added to existing brick and mortar buildings or those built using other modern methods of construction.

Fig 2. Sub-assemblies & Component

Modular

Always leading the discussion. Modular Lighting Instruments has been making high quality architectural lighting with attitude since 1980. Architectural lighting is about finding the right balance. Between the aesthetic appeal of a space and the function and quality of the light. In other words, creating architectural beauty but also making sure that it serves our needs.

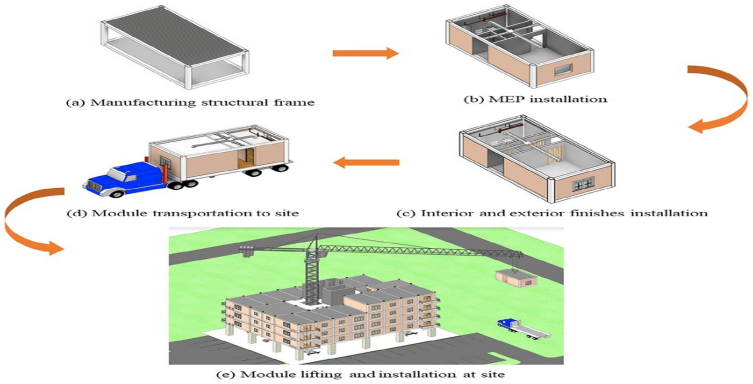

Fig 3. Modular

Volumetric

Volumetric construction, sometimes referred to as modular construction, is characterised by the off-site design and manufacture of 3-D units. Units are assembled under factory conditions which is believed to increase speed, which in turns lowers production costs. Units are typically made of timber or steel and are transported to site with all internal fixtures and fittings intact. Once on site, the units are simply stacked on top of pre-cast concrete foundations.

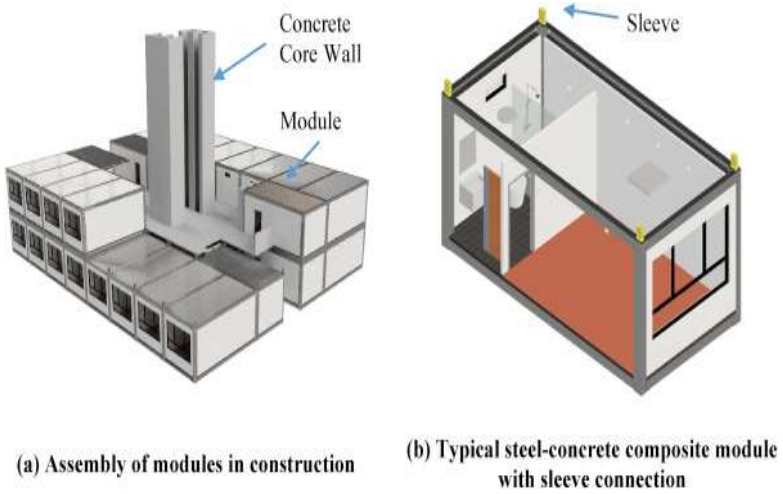

Fig 4. Volumetric

Pods

Pods, such as factory assembled kitchens and bathrooms, are designed to slot into existing structures. The manufacture of pods is similar to the methods used in volumetric construction and they are usually made from timber, steel or concrete.

Fig 5. Pods

On sit

A construction site is an area or piece of land where construction work is taking place. Sometimes construction sites are referred to as 'building sites'. This usually implies that buildings or houses are being constructed, whereas 'construction site' covers a wider scope of work.

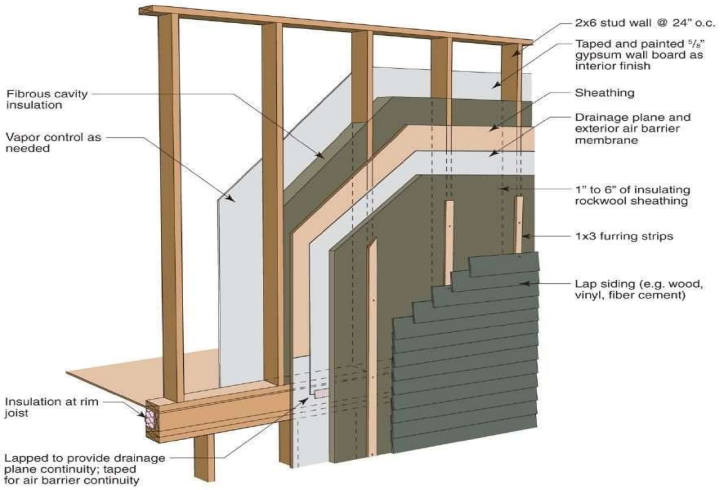

Fig 5. On sit

Methodology

The term research design refers to a framework or a detailed plan used when conducting research. It is also referred to as a strategy employed by researchers when searching for solutions to an established research problem [18]. It, therefore, involves a comprehensive and logical integration of elements such as data collection methods, research approach, and data analysis and presentation. The research design employed is said to be a critical factor in the determination of authority, trustworthiness, and authenticity of the data obtained and the research findings [19].

According to Lewis (2015) [19], the choice of a research design to be used in a study is heavily dependent on several factors. First, the choice depends on the context of the research problem, paradigms, perspectives, and the assumptions made during the research. Secondly, the choice on the feasibility of the available options as well as on the nature of the research aims and

objectives. Lastly, the choice depends on the nature of information that the research seeks to establish. Similarly, Fellows and Liu (2015) [18] observed that the choice of research design is significantly influenced by the phenomenon being explored and the proficiency of the research.

Data Collection

The study used both primary and secondary methods of data gathering, which allowed the data obtained to complement each other. The primary methods of data collection took the form of survey whereby the questionnaires were sent out to the academicians and the practitioners in the construction industry. The selected sample included 5 construction firms and 30 academicians in the field of construction, based in the same country. Convenience sampling was applied because the sample had to be in the building industry and aware of the application of SMMMC. The questionnaires used incorporated both open-ended and close-ended questions. Secondary sources, on the other hand, took the form of literature from various sources discussing SMMMC. They included books, journals, and online articles. Besides, the study used a mixed research approaches where both qualitative and quantitative techniques were applied. The use of a mixed research design ensured that the shortcomings of one technique were overcome by the other [20]. Quantitative methods adopt approaches that are scientific, and in which the study of theories and that of the existing literature, leads to precise aims and objectives. Additionally, quantitative methods result in a hypothesis that can be tested and explained [18]. On the other hand, qualitative research entails the exploration of the topic being investigated and, in some instances takes place without prior formulations. This is typically done with the aim of collecting and understanding data collected. Qualitative research thus tends to be exploratory [21], [22].

Interview

A semi-structured interview offers structure, while also being flexible to allow for unanticipated ideas to emerge [23]. Likewise, another advantage is that data can be recorded and reviewed several times by the researcher to help produce an accurate interview [24]. Therefore, semi structured interview is a more balanced form of qualitative data compared to using unstructured interviews, where there are no set questions prior to attending the interview. In contrary, Rubin & Rubin 2005 [23] criticized interviews as being ‘time consuming for data collection and analysis’ which is a disadvantage for this method as [24] also agrees as well. Nonetheless, interviews enable a greater level of detailed response because it facilities interviewees to ‘speak in their own voice and express their own thoughts and feelings’ [24]. Observational and experimental will not be used in this research due to this paper being a mostly researched based study.

Data Analysis

Since the research sought to establish the time- and cost-effectiveness of SMMMC in the housing sector, questionnaires and review of literature were used as the primary data collection methods. The literature review ensured that the results obtained were of high quality and could be generalized. In this case, due to the incorporation of both qualitative and quantitative approaches, the data was analyzed by first being converted into textual and statistical forms, which allowed the researcher to understand the information and make inferences. Some of the data obtained were presented mathematically to allow statistical conversions to be carried out [25-26].

Ethical Considerations

It is generally agreed that there are five broad ethical considerations that a researcher is supposed to make in the course of his/her study [27]. They include voluntary participation, anonymity, and confidentiality, informed consent, the potential for harm, and communication of the results. In order to address all these ethical issues, the respondents were introduced to the subject matter to ensure that they understood the aims and objectives that the research sought to achieve. In addition, the respondents were given a form that asked them to give their consent for participation in the research. The content matter of the questionnaires was formulated in line with the aims, as well as the objectives of the study.

Results and Discussion

Questionnaire

Evidence from the literature indicates that a significant number of houses are still being built using the conventional methods of construction [29]. However, the utilization of SMMMC for housing has increased in the past few years due to several factors including the growing demand for faster construction and scarcity of skills. Nonetheless, there are still uncertainties about the extent of SMMMC application in the housing sector [11]. A few large private organizations are said to have lately invested a significant number of resources in SMMMC plants and therefore the production is expected to increase. For instance, it is estimated that at least 25,000 homes per year will constructed using SMMMC [13].

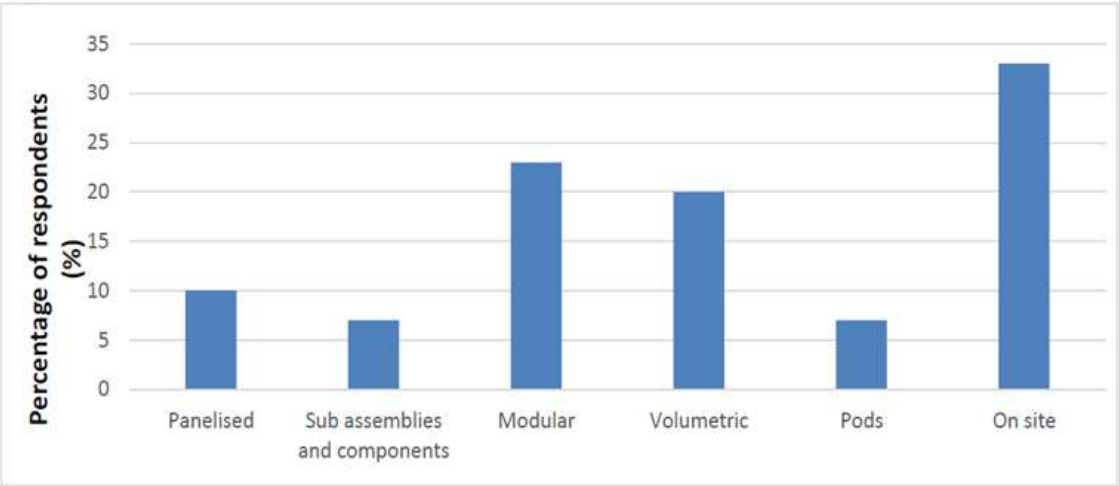

Figure 6. Types of SMMMC is used in the company/project

Figure 6 represents the answers to (Q1) on the survey aimed at finding which types of SMMMC is used in the company/project. The results depict over 30% of the 30 participants involved is using on-site SMMMC. Therefore, this suggests traditional methods of on-site construction are still being used compared to off-site SMMMC. However, modular, which is an off-site construction, is appeared to be used frequently across the companies as portrayed from the chart with a figure of 23% using it. To follow, volumetric is being used which shows 20% of the respondents using this type of modern method of construction. Thus, clearly indicates the growth of off-site SMMMC is still not apparent in some housing companies as not many companies are using off-site as expected in this survey.

Figure 7. Portrays the response of the house builders aimed at finding out the benefits of using SMMMC in the housing industry

Figure 7 portrays the response of the house builders aimed at finding out the benefits of using off-site SMMMC in the housing industry. The key benefit from the majority of respondent's viewpoint is relayed due a faster construction process impacted on the project with 20% of 30 participants agreeing to this. Following on, it is shown the total cost reduction is agreed with 17% of the respondents, indicating time savings are more apparent than cost savings. Moreover, other benefits are considered such as reduced health and safety risks. However, 'high quality materials' were not deemed to be an advantage as less than 10% respondents agreed to this benefit of using off-site SMMMC.

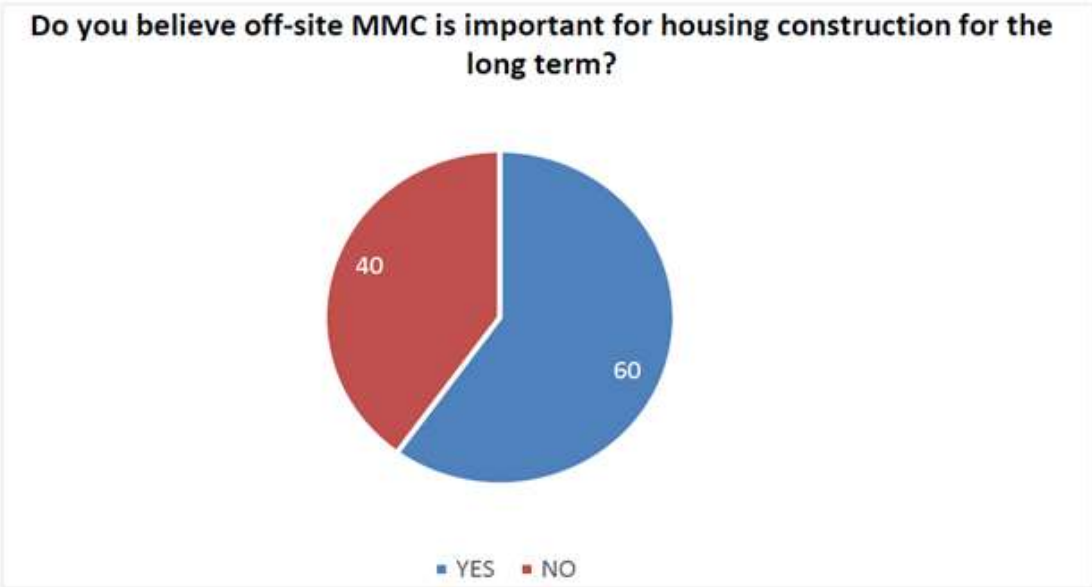

Figure 8. The respondents agreeing to SMMMC construction

Figure 8 represents majority of the respondents agreeing to off-site SMMMC construction being important for the long term with 60% saying ‘yes’. This high percentage demonstrates the possible rise off-site methods being used more in the housing companies due to the benefits. However, 40% of the respondents said ‘no’ out of the 30 results obtained in this study.

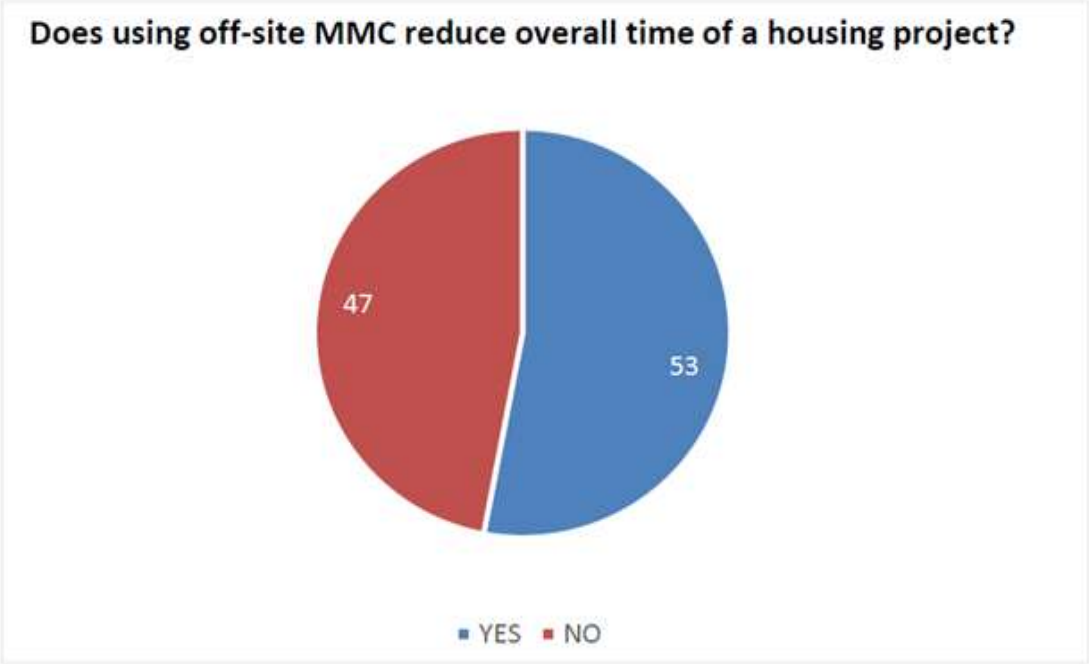

Figure 9. Off-site SMMMC reducing the overall time of a housing project

Figure 9 illustrates the respondents’ views of off-site SMMMC reducing the overall time of a housing project. Figure 11 shows a value of 53% of the 30 participants surveyed that said ‘yes’ to off-site construction reducing the time, implying time savings are saved. However, 47% agreed to time savings not being saved using off-site construction.

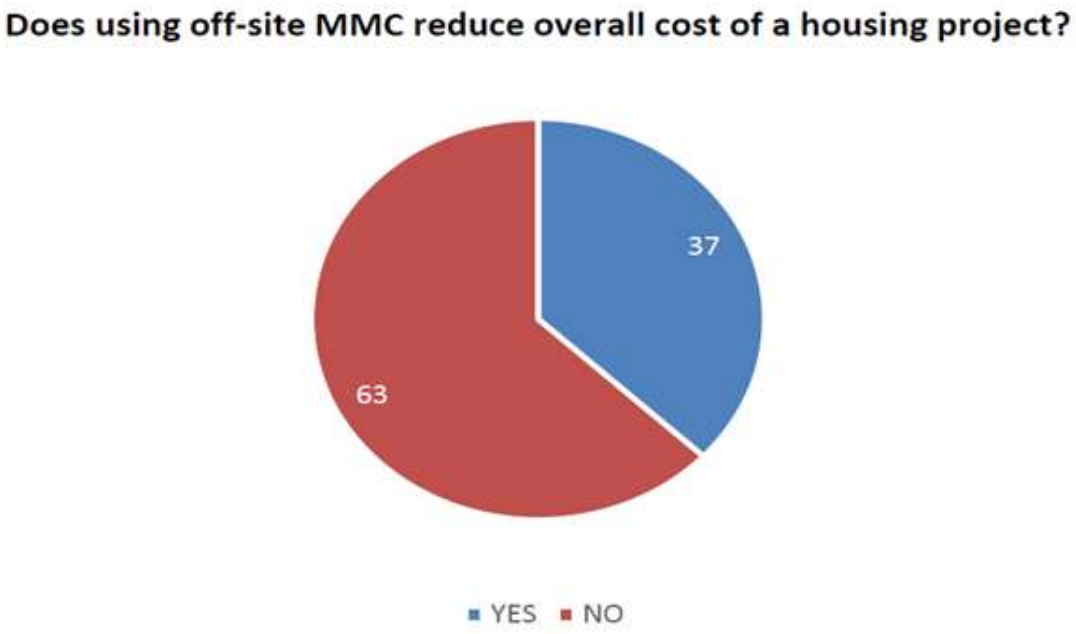

Figure 10. The SMMMC can reduce the overall cost of a housing project

Figure 10 exemplifies the respondents' perspective regarding whether off-site SMMMC can reduce the overall cost of a housing project. It shows 63% answered 'no' implying cost savings are not reduced by using this method whereas 37% said 'yes'.

Variable	Frequency	Percentage (%)
Strongly disagree	0	0
Disagree	1	3
Neutral	2	7
Agree	7	23
Strongly agree	19	63
N/A	1	3
Total	30	100

Table 1. High initial/capital costs

The data in Table 1 suggests there is high initial and capital costs as majority of the respondents, 63%, strongly agree with this. Therefore, indicating off-site is not as effective as costs are high initially, therefore less is saved on total project.

Variable	Frequency	Percentage (%)
Strongly disagree	2	7
Disagree	6	20
Neutral	4	13
Agree	8	27
Strongly agree	10	33
N/A	0	0
Total	30	100

Table 2. Reduced overall project time

Table 2 represents the reduced time overall in the projects with over 50% agree with time savings being reduced in off-site construction. However, just over 25% disagree with this.

Variable	Frequency	Percentage (%)
Strongly disagree	0	0
Disagree	1	3
Neutral	2	7
Agree	7	23
Strongly agree	19	63
N/A	1	3
Total	30	100

Table 3. Efficient construction process time

Table 3 indicates majority of the respondents, amongst 63% of 30 people strongly agreed with an efficient construction time with off-site MMC. Very little disagreed with this with only 10% in total.

Variable	Frequency	Percentage (%)
Strongly disagree	2	7
Disagree	3	10
Neutral	4	13
Agree	15	50
Strongly agree	5	17
N/A	1	3
Total	30	100

Table 4. Improved site efficiency regarding time

Table 4 shows is a high percentage of respondents agreeing with an improved site efficiency regarding time. Only 17% of the 30 people disagree with this, however, majority of off-site construction takes place from the construction site to the factory for production therefore time is effectively saved.

Variable	Frequency	Percentage (%)
Strongly disagree	1	3
Disagree	1	3
Neutral	13	43
Agree	8	27
Strongly agree	5	17
N/A	2	7
Total	30	100

Table 5. Increased number of houses built in the UK

Table 5 portrays majority of house builders have a 'neutral' opinion regarding the number of houses build using off site methods. This may be due to the lack of understanding and awareness of such methods providing benefits to the construction industry.

Variable	Frequency	Percentage (%)
Strongly disagree	7	23
Disagree	2	7
Neutral	1	3
Agree	6	20
Strongly agree	13	43
N/A	1	3
Total	30	100

Table 6. Reduces speed of construction

The data in Table 6 shows 43% agree with a reduction of speed applied with off-site construction, however, 23% of 30 respondents disagreed with this.

The interviews conducted regarding this objective indicated that a substantial number of house constructors and housing organisations are utilising, or have considered, at least one modern method of construction in their building plans. Of all the interviewees from large and medium-sized housing companies, only three claimed to have not applied or considered at least one form of MMC in the past 5 years. According to most participants, the most com-monly used form of MMC includes sub-assemblies and components, panellised systems, semi-volumetric and vol-umetric constructions respectively. Almost three quarters of the house builders and half of the housing companies inter-viewed in this study claimed to have used sub-assemblies and components. However, opinions remain divided with more than half of the participants in each case indicating to have rejected or not likely to consider using them at all.

Majority of the participants indicated that the apparent lower utilisation of MMC by housing companies might be because of the procurement of new houses through design and building contracts or under Section 106 agreements. One particular respondent noted, "The housing companies have not been able to fully adopt the modern methods of construction partly due to Section 106 agreements and the development of new homes through design and building con-tracts. Procurement of new homes through these approaches means that the companies may not always have a chance to choose the construction method used." By region, the South East and London were found to have the highest utilisation of volumetric and semi-volumetric

construction. On the other hand, Scotland has the highest utilisation of panellised system MMC, which according to Lehmann (2013) [30] is because of the well-established culture of using timber frame in construction. The region has also been credited with the highest utilisation of off-site made (OSM) sub-assemblies and components.

Form of MMC Percentage	(%)
Panellised systems	50
Sub-assemblies and components	75
Volumetric	15
Semi-volumetric	10
Site-based MMC	20

Table 7. Results of the utilisation of MMC

Positive Impact of SMMMC in the Housing Segment

Finding out the positive impact that SMMMC may have had on the housing industry was another core objective of this study. A review of the available literature regarding this issue indicated that the evidence of SMMMC benefits is still inconclusive, considering that only few studies have investigated the matter. However, the participants interviewed in the present study associated SMMMC to several benefits including, energy saving, addressing the existing skills shortage, reduction in wastes, fewer trips to and from the sites, improved quality of buildings and health and safety of workers.

The majority of the participants (construction firms and academicians) indicated that homes constructed using SMMMC require lesser heating energy than those built using the traditional methods of construction. For instance, one of the respondents argued, "SMMMC homes have more insulation components on the walls and roofs than the conventional houses, thus reducing the amount of energy required for heating. Moreover, there are fewer air leakages from the houses." It also emerged the increased interest in SMMMC among the construction companies is because of the anticipation that the energy requirement regulations will soon become stricter.

Another positive impact of using SMMMC in house construction is the reduction of wastes resulting from on-site processes. A review of the literature indicates that waste from the construction and demolition processes accounts for 25% waste [28]. As such, over three-quarters of the participants expressed their confidence that the use SMMMC is going to reduce the amount of waste being produced around the building sites. One particular respondent observed, "The use of modern methods of construction allows factory components to be ordered to the correct specifications, thus limiting the risk of on-site spillage, especially during wet weather."

The use of SMMMC was also found to have a positive impact on the transport cost because fewer trips to and from the construction sites are required. According to one of the participants, "the development of a significant portion of a house in factories reduces the overall number of trips to a construction site." The participant further observed that most of the construction works are often carried out on ‘brownfield' sites in the cities, and therefore the use of SMMMC or off-site manufacturing is crucial in that respect. More than two-thirds of the participants

cited health and safety of workers as one of the most significant benefits of using SMMMC. Statistics indicate that the construction sector is one of the most dangerous with regards to the safety of workers, with close to 100 fatalities per year in the United Kingdom being associated with the industry [13]. For this reason, most participants claimed that MMC is safer than the traditional methods since the risk of accidents in a controlled factory setting is significantly reduced, with workers also spending less time on the building site.

Cost-effectiveness of Using SMMMC Compared to Traditional Methods

There were mixed opinions among the participants concerning the cost-effectiveness of modern methods of construction in comparison to the traditional ones. A significant number of house builders argued that SMMMC are cheaper than the conventional methods while others indicated that SMMMC leads to an increased cost of construction by around 8-10%. The majority of the respondents were unable to differentiate the cost-effectiveness of the two methods. They claimed that the confidentiality of project financial information and variations in the building costs of the traditional methods make is it difficult to make comparisons.

In addition, though SMMMC is said to have a significant potential to lead to reduced initial costs, increased cash flow, and faster sales returns [17], only 45% of the participants indicated to have experienced cost reduction and enhanced profitability. The majority seemed undecided on the cost-effectiveness of SMMMC in comparison to the conventional methods. Furthermore, the use of SMSMMMC was not considered to have reduced the dependence on specific construction materials such as bricks, which are critical regardless of the construction method used. For this reason, 80% of the respondents disagreed with the notion that the use of SMMMC minimises the cost of materials. However, 60% of the house builders interviewed in this study agreed with the statements that: (1) SMMMC minimises service utilities cost; (2) SMMMC minimises labour cost; and (3) SMMMC minimises maintenance cost.

Discussion

The survey results and a review of the literature indicate that the utilizations of SMMMC in the housing sector is still not up to the required levels. A significant number of the house builders are still satisfied with the conventional methods and are not ready to embrace SMMMC. This scenario, however, does not necessarily imply that house builders are not aware of the potential of SMMMC to revolutionize the construction industry. Instead, the low level of contentment with the use of SMMMC may be due to the existing apathy in the utilizations of such methods [13], with the majority of builders, unsurprisingly, indicating that they have considered applying at least one form of SMMMC. Moreover, because most of the participants had little experience with the technologies, their opinions may have been influenced by the existing perceptions about SMMMC. Regarding the positive impact of SMMMC on the housing sector, this study has shown that the benefits of the methods are yet to be clearly understood. However, those who have used the methods associate them with several benefits, with key among them being cost and energy savings and an improvement in the health and safety workers. Although there is still no sufficient evidence concerning these particular benefits, it is clear from this study that the use of SMMMC has a significant potential to contribute to the government agenda of reducing the amount of energy consumed, mainly on heating and other housing-related activities. Moreover, the use of SMMMC is likely to reduce the transport and labour costs, with fewer trips and labourers being required on-site. This observation is consistent with the findings made by Taylor, (2010) [7], who indicated

that SMMMC often apply off-site manufacturing of components, which reduces the number of workers required on the construction site and the number trips in and out of the sites. The cost-effectiveness of SMMMC in comparison with the traditional methods appears to be unclear because the cost has been cited as both a barrier and a benefit. According to Pan and Sidwell (2011) [17], one of the main reasons as to why some people view the cost of using MMC as high than the traditional methods is because some benefits such as improved quality of buildings and fewer mistakes are not reflected in the project accounts.

The time-effectiveness of SMMMC also seemed to divide the opinions of the participants, with half of the construction companies being uncertain about the benefit. However, there seemed to be a consensus among the house builders that MMC is faster than the traditional methods, with all those who have used the methods citing speed as the main reason as to why they choose to apply them. Pan and Sidwell (2011) [17] noted that the housing companies might not be convinced of this benefit because some them do not have direct control over the planning because of their dependence on the contractors [29-31].

Conclusions

This study sought to establish the cost and time-effectiveness of utilising SMMMC in the housing sector. Inclusively, it has been established that SMMMC has a significant potential to play a leading role in addressing the current housing shortage and improving the efficiency of the construction processes precisely. Against the backdrop of insufficient adoption of SMMMC, this paper investigated the perspectives of the construction companies and house builders regarding the effectiveness of SMMMC using a survey sample of 5 top construction firms and 30 academicians in the field. The study has established that, though there are still uncertainties about some of the benefits of SMMMC, the conventional drivers such as speed, quality, performance, and cost remain critical factors in the adoption of SMMMC.

The study also suggests that modern methods of construction are efficient in terms of time compared to the traditional methods. However, more analysis and empirical research need to be conducted to establish their cost-effectiveness because the stakeholders in the industry seem uncertain about the benefit. Factors such as energy saving, reduction in wastes, reduction in transport cost, improved quality of buildings, and health and safety of works appear to be the most significant impacts that SMMMC have had in the housing sector. Nonetheless, it has been established that the perceived higher capital cost has been one of the major obstacles to the utilizations of SMMMC and therefore the strategies revolve around changing the public perceptions and provision of guidance in the decision-making processes.

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