MANAGING THE BENEFITS AND IMPEDIMENTS TO OFFSITE CONSTRUCTION IN THE UK CONSTRUCTION INDUSTRY

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The use of offsite methods of construction has long been recognised as a suitable method for increasing the supply of housing and addressing productivity in the construction industry. Whilst the literature is rife with the many benefits of the modern methods of construction as well as barriers to its implementation, its adoption remains relatively low. This study contributes to the discussion by investigating the strategies for further harnessing the benefits of the increasingly important method of construction as well as the measures for mitigating its challenges. In line with the tenet of phenomenological research, which seeks to explore the phenomenon from the perspectives of the industry experts, 12 interviews were carried out with construction professionals. The data were analysed using thematic analysis, thereby unravelling the emerging themes that emanated from the interviews. After identifying such benefits of offsite construction as increased built quality, waste mitigation, and time efficiency, among others, the strategies for maximising these benefits were presented. These include enhanced training, use of digital tools, standardisation of building components and more efficient pre-planning activities, among others. Similarly, impediments to the use of offsite construction techniques such as its high initial cost, negative stigma, non-supportive project delivery models and clients' resistance could be addressed through some measures. These measures include the development of new supply chain management model, training and education, enabling legislation and vertical integration within companies. This study will help to identify the measures for enhancing the adoption and implementation of offsite technologies in the UK construction industry. Future research is recommended to assess the government's role in being the driving force behind implementing prefabrication-specific policies and incentives to encourage its future use.

Keywords: prefabrication, off-site construction, productivity

INTRODUCTION

Offsite construction is increasingly gaining momentum in the construction industry because of the need for expedient delivery, technologically advanced as well as the renewed government backing (Siebert *et al.,* 2019). The objective of this is to deliver to the construction site, elements that are in an advanced state of completion, which remove substantial site activities from the construction process. Using offsite method,

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buildings are manufactured offsite, assembled on site, and have the benefits of high project predictability, faster delivery, less disruption, less site accident rate, improved health and safety and less waste, among others (Goh and Goh, 2019; Smith, 2011; Ajayi *et al.,* 2015). Due to its many benefits, various government reports into construction productivity and housing supply, including Latham 94, Egan 98, Barker 2004 and Farmer 2016, have identified offsite technique as a critical enabler of the industry's productivity. However, there has been a reluctance to change within the industry that is known for innovation-bias and risk aversion (Sinesilassie *et al.,* 2017).

Although the concept of prefabrication, often referred to as offsite construction, modular construction, prefabrication and Design for Manufacturing and Assembly (DfMA), among others, has been in the UK since the 1950s (Harrison *et al.,* 2012), the primary production comes from smaller house builders who may build only a few hundred a year (Bury, 2017). The most notable early use of prefabrication in the UK is the housing made in factories built in significant quantities after WW2 to address the housing shortage. The Government used the factories previously used to make military equipment to produce the housing. At the time the homes were quite expensive, but due to the shortage of labour and materials, this was the only way to address the issue (Harrison *et al.,* 2012).

Meanwhile, the use of offsite techniques is increasingly becoming the industry standard in many nations. Countries such as Japan, Sweden, Germany and The Netherlands are pursuing this technology very seriously. 80% of detached housing uses prefabricated elements in Sweden, 40% of all apartments are prefabricated in Japan, 20% of new Builds in The Netherlands use these elements, and 9% of all new residential permits are for prefabricated buildings in Germany (Steinhardt and Manley, 2016). In the UK, it is thought that no more than 2% of construction work has any significant prefabrication (Steinhardt and Manley, 2016).

Literature is rife with the benefits of offsite construction as well as the barriers to its implementation (cf. Hong *et al.,* 2018; Pan *et al.,* 2008). Despite this promising nature of the construction technique, its level adoption remains disappointedly low. What the literature currently lacks is the direction on how to enhance the uptake of offsite construction. For instance, Killian *et al.,* (2016) identified the barriers and challenges to offsite construction but offered no solution for facilitating its adoption. Rahimian *et al.,* (2017) and Arif *et al.,* (2017) also identified the barriers and challenges to offsite construction without proffering solutions on how its hindrances could be addressed. While many studies identified its benefits (cf. Goh and Goh, 2019; Siebert *et al.,* 2019), there has been less focus on how such benefits could be maximised. By engaging the industry stakeholders, this study fills the gaps in the literature by identifying the strategies for maximising the many benefits of offsite construction as well as the approaches for minimising the barriers to its implementation. The benefits of offsite construction, as well as the barriers to its implementation, were identified and experts in offsite construction were then engaged to identify how to facilitate an improved use of offsite construction in the UK construction industry.

In line with the goal of this study, the next section presents a review of the literature on the benefits and barriers of offsite construction. The section is then followed by the presentation and justification of the methodological approach and the findings of the study, which is discussed before the paper culminates in the conclusion and implications of the study.

LITERATURE REVIEW

Goh and Goh (2019), among many other authors and practitioners, suggest that prefabricated components in comparison to onsite construction can achieve a better-quality product. This is due to better supervision as well as the associated quality assurance standard in a factory environment (Smith, 2011). Blismas and Wakefield (2009) found that prefabrication delivered better consistency, quality and component life while reducing whole life cost and defects. This is achieved through quality assurance in a controlled factory environment and the ability to use highly specialised equipment in controlled conditions. However, in a defects study undertaken by Johnsson and Meiling (2009), although there was an increase in quality, defects still occurred with 10% being linked to the lifting and transporting of the prefabricated components, including up to 2 years after the installation. These were directly linked to errors caused in the factory. As such, notwithstanding that quality is improved through the efficient use of skilled labour and machinery, proper attention must be paid to lifting and transportation, which could otherwise lead to defects and prevent superior quality associated with prefabricated components.

Another significant benefit of adopting prefabrication is the reduction of onsite construction time due to the possibility of simultaneously constructing in the factory while the onsite work is being done (Smith, 2011). Due to this, the required number of processes is reduced and simplified with the potential for time-saving, while also overcoming the possible impact the weather. In an example by Smith (2011), it is stated that a home was able to be built in a factory and then moved to the site and installed during conditions which would not have been suitable for traditional types of construction. Notwithstanding these benefits, Goodier and Gibbs (2007) noted that longer lead times could delay the beginning of the project, and to reduce this, the whole design and construction process needs to be more aligned. What this means is that even though time on site may be shortened as described by Smith (2011), what is not accounted for is any pre-planning and lead times to the use of prefabrication which may cause delays before onsite construction is started. Blismas and Wakefield (2009) also agree that on-site duration is shortened but argued that the usual estimation does not account for changes and knock on effects during production or onsite installation.

It is often argued that the cost of using prefabrication is often cheaper than the on-site equivalent. In line with this, Blismas and Wakefield (2009) suggest that prefab is a significant contributor to reducing whole life cost of construction through lower site related costs and earlier income generation for clients (Blismas and Wakefield, 2009). Prefabrication is widely believed to be capable on can achieving more productivity, and thereby reduces the cost of labour. However, some authors suggest that there are hidden costs that unaccounted when calculating the actual cost of the prefabricated units. A study carried out by Friedman (1992) considered 15 house builders in the Canadian market and their production of family homes. It was found that prefabrication was around 15% more expensive in comparison to traditional methods. This was due to the initial investment for a factory and the need to hire staff all year round. This is unlike the traditional method that only hires workers only when required. Smith (2011) also believes prefabrication is touted as being more cost-effective, and its cost is made up of 3 aspects - Material, Labour and Time - and in theory, a reduction in one will mean a reduction in costs. However, what is missed here and explained by Blismas and Wakefield (2009) is that prefabrication may suffer from an increase in design and transport cost if they are being transported over a long

distance. This implies that although prefabrication appears to be a cheaper alternative to traditional methods, but when considered further, many factors determine the cost.

In the industry that is well known for a high rate of fatality, prefabrication is perceived as a safer alternative to traditional construction. In a factory, processes can be carefully planned to minimise risks, making work safer. Another benefit to offsite construction is the ability to control wastage which would typically occur on a traditional site (Ajayi *et al.,* 2015).

Notwithstanding the many benefits of offsite construction, there are also barriers to its implementation. Generally, before a company can start to produce prefabricated component, a factory is required to be built. It is reported that that prefabrication has a high initial cost (Goodier and Gibb, 2007) and that to setup costs are also quite high (Blismas and Wakefield, 2009). There is also a general perception within the housebuilding industry that building homes using prefabrication is more expensive than the conventional methods of construction and therefore creates a barrier to its use. This can be seen in a survey undertaken by Pan *et al.,* (2008), involving 100 house builders, where they believed higher capital costs to be a significant barrier to prefabrications use. Notwithstanding the initial cost, it is widely believed to have a whole reduced life costing (Goodier and Gibb, 2007).

A study by Blismas and Wakefield (2009) identified a general lack of guidance and information on prefabrication as a significant barrier to its implementation. This lack of knowledge can also be seen in a study on the UK's house builder's utilisation of prefabrication. The study found a lack of previous experience as a very significant factor in not using prefabrication (Pan *et al.,* 2008). This further backs up what Blismas and Wakefield (2009) identified, suggesting that even if a company may want to get involved in using prefabrication, the limit on the amount of information is proving to be a significant barrier.

The current method to build homes has been in place since the first homes were built; so many builders are reluctant to change this method, and the builders are attached to conventional building methods and their current roles and tasks. This is mainly as the industry is known to be resistant to changes (Hairstans, 2014). However, the blame for this barrier cannot all be blamed on the people reluctant to change. The current business model is also set up for a more traditional house building technique. It is suggested that prefabrication will require different payment terms and cash flow arrangements (Blismas and Wakefield, 2009).

Much of the current literature on prefabrication pay attention to the negative stigma attached to prefabrication. This is the perception of prefabricated homes from potential clients and end users. The negative association may cause people to avoid using prefabrication and opt to go for a more traditional style of housing. A case study on the constraints and barriers to prefabrication highlighted this and stated that the negative connotation related to prefabricated construction comes from the association with unsafe and poor construction that was previously used (Schoenborn, 2012). This is most evident in a report on the barriers to offsite use in the UK, which suggests that out of a sample of contractors 48% found there was a negative image associated with prefabrication are a potential barrier to its use (Goodier and Gibb, 2007).

RESEARCH METHOD

Data Collection

To elicit experts' opinion, based on their personal experience of the concept, phenomenological research is a useful approach (Creswell, 2013). This allows researchers to bracket out their experience in a bid to get the first-hand experience from the participants. As such phenomenological approach was used in the study. Interviews were carried out with 12 information-rich participants to explore the strategies for maximising the benefits of offsite construction as well as the measures for mitigating its barriers. This approach allows the researchers to gain in-depth view of the concept by interacting with information-rich participants (Creswell, 2013). In line with Creswell (2013) position that purposive sampling allows researchers to select the most appropriate respondents, and Polkinghorne (1989) recommendations that between five and 25 respondents are suitable for a phenomenological study, 12 respondents were purposively selected for the study. Table 1 presents information about the participants, with their years of experience of prefabricated components and offsite construction ranging from 5 - 21 years.

Table 1: Overview of the research participants

Categories of respondents	Number of participants	Interviews Nos	Average years of experience
Designers (Architect, Arch Technologist, Civil Eng.)	3	1, 12, 4	14
Construction/project managers	3	2, 3, 6	12
Components manufacturers	3	5, 8, 11	7
Foreman	1	9	21
Site supervisors	2	7, 10	16

The participants were informed of the identified benefits of offsite construction and were asked to reflect on how such benefits could be maximised to enhance its increased adoption in the industry. Also, they were asked to explain how the current hindrances to the broad adoption of the modern method of construction could be mitigated. The 12 interviews were carried out face-to-face within six months, and they were recorded with the participants' consent and transcribed for qualitative analysis.

Data Analysis and Findings

Content-driven thematic analysis was used to explore the implicit and explicit statements stemming from the transcribed data (Braun and Clarke, 2006). This approach allows a systematic process of data analysis that flow from narrow to broader unit of analysis (Creswell, 2013). The initially identified themes were further analysed to identify the broader categories of strategies for maximising the benefits of offsite construction and mitigating its impediments. Table 2 shows the identified themes, their sub-categories and the interviews from which they emanated.

DISCUSSION

This section discusses the findings of the study under the six main themes in Table 2.

Increased Digitalisation of the Construction Industry

Better use of technology was recognised as being an essential enabler of prefabrication, as it is capable of increasing build quality and minimise waste (Smith

2011). One respondent stated that "the industry must start innovating and first movers will see immense benefits and possibilities for gaining a competitive edge." It was recognised that "implementation at the design stage using BIM is where to start". This aligns with Smith (2011) who suggests that the future of prefabrication relies on BIM, which allows prefabrication to be flexible, through virtual simulation. As one respondent suggests, "it allows the company to identify parts of the building that can be done in a factory", giving confidence to the designers and contractors and allow them to push the limits. Nonetheless, using technological advancements to maximise the benefits of prefabrication does not stop with BIM. Changes in technology can be introduced at a production level. An example suggested by one respondent was that "technological advancements allowed wax models to be 3D printed and used and recycled in the casting of concrete". As such, further incorporation of new technology at both a design level and production level can go a long way in maximising the benefits of prefabrication. Further advances in industrial machinery and digitalisation will allow the processes to be even more precise and deliver an even product.

Government Facilitation of the Modern Method of Construction

Introduction of enabling legislations is a crucial measure for facilitating prefabrication. An interviewee suggests that "an increase in not only UK government strategies but EU policies as well could further reduce the time needed on site." This is especially as the respondents believe that "building regulations are not really suited to the use of prefabrication and often several visits are needed by planning inspectors". This means that government intervention at a regulatory level could help to maximise the benefits of prefabrication, especially as the government's own review suggests that the current policies are not supportive (Parliament, 2003). Such intervention will not only include the introduction of enabling legislation, but it will also require the government to demonstrate the method in their affordable housing scheme. The use of the government's purchasing power to facilitate a compulsory proportion of offsite components, similar to BIM level 2 mandate, will significantly drive the use of offsite construction. Where possible, the risk put on a company should be minimised. As one interviewee suggested, their company's receival of a grant to deliver homes was an excellent motivation for offsite construction. This suggests that an increase in grants could help reduce the risk for the companies and in turn encourage more companies to build factories to produce prefabricated homes.

Standardisation for Offsite Construction

The respondents believed that the slow progress in the use of offsite technology is partly due to the insufficient information available on the increasingly important method of construction. This is mainly as there is currently no industry-wide standardization of the components and element, in addition to the lack of sufficient performance standards for offsite construction. As one interviewee put it, "instead of focussing on standard house type, the industry should aim at mass customisation of building elements and components". "This will help the designers to drive offsite construction by designing for it". In line with this, Bertelsen (2005) adds that unlike traditional building components, there is no catalogue for existing prefabricated components to use in designs. This suggests that a designer willing to incorporate prefabrication may find it hard because the information is not easily available there. It is suggested that "standardisation of housing specification requirements" by key housing providers, such as housing associations and local authority, will go a long way in facilitating components standardisation.

Table 2: Identified strategies for enhancing the use of offsite construction

Theme identified from interviews and their sub-categories	Interviews
Theme A: Increased digitalisation of the construction industry	
A1: Increase the use of technology to enhance precision in factory	2, 3, 4, 5, 8, 11, 12
A2: Use of innovative products to aid factory works	1, 5, 8, 11
A3: Innovative technology to enhance factory waste reuse	3, 5, 8, 9, 10
A4: Increased use of technology for easier planning/sequencing	2, 3, 4, 5, 6, 8, 11
Theme B: Government facilitation	1, 2, 3, 4, 5, 7, 8, 9, 11
B1: Introduction of government policy to accommodate prefab	1, 2, 3, 5, 6, 7, 8, 10, 11, 12
B2: Affordable housing development through offsite technique	3, 5, 6, 7, 8, 10, 11, 12
B3: Govt. approval through grant funding for offsite delivery	1, 2, 4, 5, 7, 8, 9, 10, 12
B4: Use of government purchasing power in similar way to BIM	1, 4, 6, 7, 8, 9, 10, 12
Theme C: Standardization for offsite construction	2, 6, 7, 9, 11
C1: Mass customisation of components/elements, not house types	2, 5, 8, 9, 11
C2: Development of offsite construction performance standards	4, 6, 7, 8, 10,
C3: Housing associations to standardise their spec requirements	1, 2, 4, 6, 7, 8, 11, 12
Theme D: Education and Training	3, 8, 9, 10
D1: Professional bodies to provide upskilling training to their members	2, 6, 7, 12
D2: Incorporation of offsite delivery into the academic curriculum	6, 8, 10, 12
D3: Factory workers to be further trained to make quality products	1, 4, 5, 8, 10, 11
D4: New apprenticeship scheme on offsite construction	8, 11
D5: Training of onsite workers to enhance quality of build for prefabs	1, 3, 5, 8, 9, 11, 12
D6: Awareness and education on the available products &specifications	6, 10, 12
Theme E: Client Education and Awareness	
E1: Showhomes as proof of concepts (quality samples) to clients	
E2: Clients' education on the long-term benefits of prefabricated homes	
E3: Construction firms as both client and contractors to showcase it	
Theme F: Development of a new supply chain model	
F1: Companies to adopt vertical integration strategies	3, 4, 5, 11, 12
F2: Change in supply chain management to suit prefabrication	2, 6, 7, 8, 9, 11
F3: Long term project planning to incorporate factory works	2, 3, 6, 9, 11
F4: Integrated project team between client, manufacturer &contractors	1, 2, 3, 6, 9, 10
F5: Government support to drive supply chain development	1, 2, 3, 4, 5, 6, 7, 9, 10
F6: Preliminary consultation with components/elements suppliers	1, 2, 3, 4, 5, 6, 7, 8, 9, 11

Note: Themes A, B, C and D were identified as benefit maximisation strategies, while C, D, E and F are identified as impediments mitigating strategies.

Education and Training of Professionals

Many similar themes emerged around the needs for increased education of AEC professionals on the offsite construction technique. This is as a result of an inherent lack of knowledge around prefabricated homes and what can be achieved through its implementation. As such, it was suggested that "training schemes could be increased to further maximise the benefits of prefabrication". In a study by Pan *et al.,* (2008), involving housebuilding companies, the skill upgrading by training was identified as a driver to increase prefabrication. It is clear that precise and thorough training could go a long way in increasing the use of prefabrication. The interviewees suggested that "striving to train people by working on apprenticeships schemes for the next worker" would be a great way to drive prefabrication. Other potential ways of facilitating the training are through short professional development courses by professional bodies

and incorporation of "offsite construction technology into the academic curriculum". An interviewee opined that "architects must start to learn how to use small details to make prefabrication more appealing".

The method to minimise the lack of knowledge around construction could start at the university level and continuously topped up with seminars and events which could be supported by the appropriate professional bodies. Materials, elements and components manufacturers also have roles to play in making people aware of their products and the available specification. Through these different levels of technical and non-technical training, depending on roles, the professionals will be more aware of the offsite construction techniques with the likelihood of driving its implementation.

Clients' Education and Awareness

Clients as the key driver of construction projects are important stakeholders that could drive the use of offsite construction. However, the clients and the public also face a similar problem and shy away from using prefabrication as a result of low awareness of its potential benefits. A respondent suggested that "a way to minimise this barrier would be the introduction of clients and even other competitors into the factory to see how things are done and a look at the finished product". This suggests that if clients and other people in the industry know the benefits prefabrication cab offer, its adoption may be easier. Steinhardt *et al.,* (2013) agreed that managing the expectations of consumers through education and comparing the traditional and prefabricated houses will serve an important purpose. With an introduction of better ways to educate people in using prefabrication and its potential results, the barriers could be minimised, and more people could be encouraged to use the technology.

Development of a New Supply Chain Model

As the initial factory cost is the main barrier to offsite construction, the respondents believed that "vertical integration of manufacturing is essential to drive innovation and continuous improvement", especially as "some good companies use prefabrication in an industry that is highly fragmented". Vertical integration is an arrangement in which the supply chain is owned by the same company that produces the product. The supply side of the industry is not particularly suited to use prefabrication and a way to solve this could be a shift in thinking. The offsite market could behave like the car industry, benefitting from economies of scale by reducing intermediaries.

Steinhardt *et al.,* (2013) opined that an integrated supply chain would bring many benefits and could be achieved by negotiations between supplier and builders. If a long term and relationships can be formed between suppliers and contractors, the housing manufacturing process has the potential to become more straightforward and efficient. The increased involvement in supply-side changes could work in reducing the barriers for the use of prefabrication. A more collaborative working that is totally different from the "over the wall syndrome" and blames culture bedevilling the construction industry (Ajayi *et al.,* 2016) will be essential for harnessing the benefits of offsite construction. For instance, a "preliminary consultation with suppliers", as one respondent put it, will be requisite for effective design for offsite construction.

CONCLUSION

Notwithstanding the positive impacts of offsite construction on construction productivity and quality, its adoption has been slowed by some barriers. Using a phenomenological approach, this study investigates the strategies for harnessing the

benefits of the modern methods of construction as well as the measures for mitigating its impediments. The study suggests that the requisite for broader adoption of offsite construction include increased digitalisation, standardisation for offsite construction government support, education and training of construction professionals, increased awareness by the clients as well as the development of favourable supply chain model.

The study implies that offsite construction could not become well adopted in the industry without proper education for both the construction professionals, who are expected to have the technological know-how, as well as the clients that are the drivers of construction projects. This requires both formal and informal trainings as well as the promotion of its many benefits by the industry stakeholders. This is especially as its adoption is still hindered by negative images among the clients. The knowledge, awareness and practice of the modern method of construction could be further expedited through an improved standardisation of the building components and elements to facilitate easy specification, reproduction and market structure for the elements. As the current supply chain model within the industry impedes the growth of offsite construction, it is essential that a more integrated system of the supply chain is facilitated through enhanced collaboration and vertical integration. With the government being major clients and enablers of the industry, the government is not only expected to create enabling legislation and provide financial incentives but are also to deliver their projects through offsite technique.

Based on emerging themes from the study, the research in this area will benefit from further studies that focus explicitly on the supply chain for offsite construction as well as the roles of government as a crucial enabler of offsite construction.

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