

Hindrances to the uptake of offsite construction

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Abstract

Pre-manufactured and offsite construction are examples of Modern Methods of Construction identified as having the potential to transform the industry. However, unlike the automobile industry, the global construction industry has not been able to fully exploit and harness the many benefits associated with the use of pre-manufacture and offsite strategies. In nearly all sectors of the global construction industry, far too much construction takes place on construction sites. Several factors hinder the breakthrough required to increase the uptake of offsite construction approaches to levels that significantly impact the industry's performance and outputs. Following a review of extant literature, the most significant constraints that hinder the uptake and increased use of offsite construction strategies are identified. Some of the impacts of these constraints on the industry's growth and development are explored as well as identifying areas for further study. This paper is based on a review of literature only and represents the first stage of a study into the low uptake of offsite construction approaches. Detailed strategies for addressing the constraints are not addressed in this paper. This will be the focus of the next stage in the broader research.

Keywords

Offsite construction, premanufactured construction, hindrances, constraints, modern methods of construction

1. Introduction

Modern Methods of Construction (MMC), off-site manufacture, and prefabrication are among a range of terms variously used in relation to construction innovation (Farmer, 2016). It has been argued that the construction industry faces an almost inevitable decline unless it embraces modern methods of construction (MMC). This is predicated on several factors which cumulatively hamper the growth and development of offsite strategies in the construction industry. Amongst these causes include the effects of the failure to replace retiring workers and low productivity within the industry. The industry can address the skills shortage and encourage greater efficiency and higher productivity in the sector is to embrace and adopting pre-manufacturing (Farmer, 2016). The construction industry generally has a reputation for projects completed over budget and behind schedule. There have been efforts by the leading firms in the industry to improve project time, cost, and quality performance through the use of technological and commercial industry innovations such as Building Information Modelling (BIM) and collaborative supplier engagement models. Whilst these initiatives have yielded significant gains, they have unfortunately failed to counter the effects of the growing challenge of industry skills shortages or reverse the trend of poor project uncertainty and low productivity (KPMG, 2016).

To address challenges within the industry, there needs to be investments in and promote innovation across the entire industry. There is no suggestion that MMC typologies, such as pre-manufactured and offsite construction approaches will address the many problems faced by the industry. However, these novel approaches present several benefits which provide a compelling case for their use by the industry for the industry's benefit (Ofori-Kuragu & Osei-Kyei, 2021). Increased use of offsite construction products will require smaller workforce numbers on site to assemble pre-manufactured elements. This in turn leads to overall safer construction sites. Whilst there is already a sizable proportion of lower-level pre-manufactured components such as windows, outer fences, and simple flat-pack 3-D structures, etc. used in construction, the levels are not sufficient.

Further research is required to explore the reasons for the low uptake. To enable the industry to exploit the opportunities presented, there needs to be coordinated stakeholder action (RIBA, 2016) to address these challenges and thus promote the uptake of MMC and premanufactured construction. Again, there must be increased investment in MMCs and in promoting these solutions to enable more clients to adopt these for their projects(Farmer, 2016).

2. Methods

This paper is the first stage of research into the constraints that hinder the uptake of offsite construction methods. This paper has been developed based on a review of recent literature on the subject with a focus on journal publications, conference papers, industry reports from the UK construction industry, and research outputs by some of the leading organisations in the field of offsite and premanufactured construction. The industry reports reviewed were mainly developed from surveys of their memberships which make them representative of larger sections of the industry.

In this paper, the main constraints from the review have been identified in Table 1. Some of the causes and impacts of the identified are discussed in this paper. In the next stage, a systematic review of literature will be undertaken to identify solutions to the identified constraints. An industry-wide survey of professionals with experience in OSC projects and module manufacture to explore their views on the solutions to the most common hindrances to the uptake of OSC.

3. Evaluation of Literature

3.1 *Offsite Construction*

The construction industry faces a race against time to embrace modern methods of construction (MMC). The Farmer Report argued that adopting pre-manufacturing as a core element of offsite construction offered the only way forward for the industry to address issues with low productivity, and skills shortage and encourage greater efficiency (Farmer, 2016). Offsite construction as a generic term incorporates the manufacture and pre-assembly of components, elements, or modules which are then installed into their final location on construction sites. It is one of the main approaches within the overarching terminology of Modern Methods of Construction (Smith *et al.*, 2015). Offsite construction has also been defined as the prefabrication, modularisation, and standardisation of construction processes and assets within controlled factory environments (KPMG, 2016). This part of the construction process carried out away from the building site can be in a factory or a specially created temporary production facility close to the construction site (RIBA, 2016).

In the true sense of the term, offsite construction “involves substantial factory manufacturing intervention to add to project value, with the percentage of on-site added value to the final construction value at project completion expected to be less than 40% (CIC, 2013). Offsite construction also produces elements or modules and offers an alternative to the status quo in the construction industry and promises transformative improvements in time, cost, quality, greater predictability, and safety (KPMG, 2016). Offsite construction thus broadly incorporates the same concepts integral to the key stages of construction industrialisation. The use of prefabrication in construction became more popular in the 1900s (Autodesk, 2019). Whilst, not a new technique, it is becoming easier to use as a result of advanced modelling techniques which enable contractors to use standardised elements using bottom-up approaches in infrastructure and building construction (Hussein et al., 2021). Prefabrication is adaptable to diverse types of structure and has the potential to help achieve important levels of standardisation, providing a key cornerstone to unlocking manufacturing-style productivity levels within the construction industry. If this were to be achieved, buildings could be manufactured in low-cost manufacturing centres and shipped to destinations anywhere in the world for final assembly (Autodesk, 2017). Such innovation could significantly improve the competitiveness of the construction industry (Sutrisna et al., 2022).

3.2 Hindrances to the uptake of offsite construction

Despite a broad acknowledgment of benefits associated with offsite construction approaches, offsite construction contributes only 7% to the UK construction GDP. Legitimate questions continue to be asked about the low uptake of offsite in the UK construction industry. Some of the barriers to the increased uptake of offsite in the UK construction industry include the prohibitive cost of entry, the need for fully front-loaded engagement with suppliers, a lack of confidence in product quality, and a lack of certification and standardisation of products (KPMG, 2016). Other typical obstacles include the overall poor image of the construction industry in society arising from misconceptions held about the quality and prices of products. Perceptions about the limited scope for customisation and the demand by many clients for individual solutions also discourage the use of standardized processes and components. Again, the limited experience amongst construction workers of the application of prefabrication especially in high-rise projects, and the generally increased risks involved in committing to particular off-site suppliers at a time the sector is in its initial stages of development with limited available alternatives (WEF, 2016).

Given the prohibitive costs involved in establishing factories for offsite manufacturing, the irregular nature of construction demand thus leads to an underutilization of the prefabrication factory space (WEF, 2016). Pinsent Masons (2017) identifies the huge upfront investments in the development of new factories for the manufacturing of modular products as a major barrier to the increased use of offsite solutions. Another criticism of modular construction is the fact that modules may be manufactured offsite and transported from distant locations to site for installation. It has been argued that this is not sustainable and does not utilise local labour (Pinsent Masons, 2017). Despite this criticism, there are instances where restrictions on site and a lack of ample space, and labour shortages make this unavoidable.

In cases where factories are located far away from construction sites, another constraint is transportation costs. It can be expensive to transport manufactured components from factories to sites where transport links are not well developed whilst some communities may oppose the transportation of huge offsite manufactured components through their localities (Choi et al., 2019).

Again, it can be a problem handling large, prefabricated components in space-constrained construction sites. Technical specifications from owners may also be a barrier to the wider use of standardisation, modularisation, and prefabrication (Wilson et al., 2019). The highly detailed designs required early on in modular construction minimises the ability to influence the design. Another major constraint to the use of modular construction is the costs associated with such developments (Pan and Sidwell, 2011). Whilst repetitive designs enable economies of scale, unfortunately, it leads to uniform and sometimes “boring” buildings. Designing for manufacture as happens in modular construction produces inflexible, expensive ugly, identikit buildings that may not appeal to many potential buyers (Jaillon and Poon, 2010). Also, in some places, local regulatory requirements reduce the cost-effectiveness of standard factory-made solutions, thus making offsite solutions more expensive and less competitive (CIC, 2013). The housing sector’s price sensitivity presents significant commercial challenges to increasing the use of offsite construction solutions in the house-building sector. Where there is a demonstrable business or project case, there is evidence that the industry is receptive to the use of offsite technologies. (CIC, 2013). An example of this is the extensive use in the UK construction house building industry of factory-manufactured truss-rafter and timber frame systems.

Durdyev and Ismail (2018) concluded that in the particular local context, skills shortage was the most significant barrier to the increased use of offsite construction solutions. However, it has also been argued that demand from the industry presently is insufficient to enable the opportunities arising from economies of scale through mass-production techniques to reduce unit prices, especially in the private sector (CIC, 2013). Other constraints to the widespread use of offsite solutions included a lack of a universally acknowledged definition for offsite and MMC, a lack of sufficient knowledge within professional ranks in the industry about the offsite solution, and a lack of R&D resources on offsite construction. There was also a lack of support from warranty bodies, lenders, and surveyors concerning offsite products (HfS, 2015).

Another aspect involves the interface between designers and manufacturers. Whilst appropriate house warranty schemes may provide warranty protection against insolvency and default of developers and contractors (BSA, 2017), the issue of how lenders to developers and house buyers will obtain warranty protection against module manufacturers is a grey area that needs to be explored (Pinsent Masons, 2017). The interfaces in the design process need to be clarified as to whether manufacturers are designers or simply building to specifications generated by other entities. Again, there is a negative effect on cash flow as contractors had to invest in offsite manufactured components in advance of receiving orders from clients. This would lock up contractor capital or compel them to borrow at a cost. The study concludes amongst other things that any movement towards offsite must be demand-led and argues that the business case for offsite is yet to be established (HfS, 2015).

Housebuilders are risk averse and would typically not adopt the use of novel technology unless there was a powerful commercial justification for taking on that risk. Again, the long lead-in associated with off-site fabrication means that payments will need to be made by contractors before the delivery of goods to the site. In cases where off-site manufacturers are based abroad, issues around shipping risk, and marine cargo insurance need to be sorted as well as the apportionment of the risk of delay which may arise from shipping as argued by Pinsent Masons (2017). In addition to this, the strong bargaining position of modular suppliers is acknowledged.

Table 1 Summary of hindrances to the uptake of OSC from literature

Barrier	Source
High cost of entry	KPMG (2016), HfS (2015), Agapiou (2022)
The need for fully front-loaded engagement with suppliers	KPMG (2016)
A lack of confidence in product quality,	KPMG (2016)
A lack of certification	KPMG (2016)
A lack of standardisation of products	KPMG (2016), WEF(2016),
Limited experience among construction workers in the application of prefabrication especially in high-rise projects	WEF (2016)
Increased risks involved in committing to particular off-site suppliers	WEF (2016)
Irregular nature of construction demand	WEF (2016)
Overall poor image of the construction industry in society	WEF (2016)
Perceptions about the limited scope for customisation	WEF (2016)
The demand by many clients for individual solutions	WEF (2016)
Local labour and sustainability implications of transporting offsite products	Pinsent Masons (2017)
Transportation costs	Pinsent Masons (2017)
Handling large, prefabricated components in constrained construction sites	Pinsent Masons (2017)
Technical specifications from owners	WEF (2016)
The highly detailed designs required early on in modular construction	WEF (2016)
Production of inflexible, expensive ugly, identikit buildings that may not appeal to many potential buyers	Pinsent Masons (2017)
Local regulatory requirements which reduce the cost-effectiveness of standard factory-made solutions	CIC (2013)
Housing sector's price sensitivity	CIC (2013)
Skills shortage	Durdyev and Ismail (2018)
Insufficient demand from the industry to enable the opportunities arising from economies of scale through mass-production techniques to reduce unit prices, especially in the private sector.	
Little likelihood of potential gains in the house-building sector arising from mass production on a scale that justifies additional investments in manufacturing costs associated with the offsite solution	CIC (2013)
A lack of a universally acknowledged definition for offsite and MMC,	HfS (2015)
A lack of sufficient knowledge within professional ranks in the industry about the offsite solution, and a lack of R&D resources on offsite.	HfS (2015)
Lack of support from warranty bodies, lenders, and surveyors	
overall costs which were seen to be higher in the case of offsite construction.	
Another aspect involves the interface between designers and manufacturers and the effects on house warranty schemes	Pinsent Masons (2017) BSA (2017)
Lack of clarity between manufacturers and designers	Pinsent Masons (2017)
Clarifying responsibilities for specification, on-site design, overall design of a scheme, and associated infrastructure need to be established.	BSA (2017)
Negative effect on cash flow due to contractor investment in offsite manufactured components	Pinsent Masons(2017)
Lack of a business case for offsite	HfS (2015),
Risk averseness of Housebuilders	(CIC, 2013).
Long lead-in associated with off-site fabrication	
Issues around shipping risk, and marine cargo insurance	
The strong bargaining position of modular suppliers is acknowledged.	
The apportionment of the risk of delay	Pinsent Masons (2017)
Insolvency risk	
Risks arising from bespoke design associated with modular construction	Pinsent Masons (2017)
The unwillingness of D&B main contractors to accept risk	(Pinsent Masons, 2017)
Lack of data on producer capacity to cope with increased demand for offsite construction inputs.	KPMG (2016)
The issue of the sub-contract terms in relation to pricing, payment schedules, and design responsibility	Pinsent Masons (2017)
Lack of compelling empirical evidence for the end-demand market	Farmer, 2016

Evidence from Agapiou (2022) indicated that cost-related barriers were perceived to be the most significant barriers to OSC use for Housing Associations. This was followed by the capacity of suppliers and end-user preferences for traditional construction. An acknowledgment that in the event a contractor opts to manufacture their modular units, they bear the design and construction risk with no recourse to any third parties. Where a contractor or housebuilder buys modules from a third party or enters into a joint venture with their party, a greater portion of the overall value of the development will be situated in that single contract (Pinsent Masons, 2017). In this case, in the event of problems arising concerning the modules, the purchase contract or joint venture agreement should provide suitable protection to the contractor or housebuilder (Goldhadr et al., 2022). Another obstacle to the use of offsite solutions in the housing sector is a lack of appreciation by the offsite sector of how the house-building industry works (Gusmao et al., 2020)FF. Most offsite manufacturers thus concentrate on sectors of the construction industry with relative ease of entry (CIC, 2013). The lack of credible evidence of the value of offsite at project, portfolio, and asset whole-life levels is a major issue as evidenced in Goulding et al. (2012).

4. Discussion

Offsite construction, premanufactured construction, and prefabrication are some of the most popular examples of the broader family of Modern Methods of Construction (MMM) which are generally acknowledged to have the potential to transform construction. It has been suggested that the very existence of the construction industry could be hinged on the uptake of these technologies. Despite several studies and compelling evidence in literature of the benefits of offsite construction, the uptake of these technologies is low. To enhance the uptake of these transformative technologies, the constraints which hinder their uptake need to be explored and innovative solutions found to address the constraints enhance their uptake. Some of the constraints are related to cost, quality, risks, economic justification, warranty, supply, and demand. In addition to the commonly known barriers associated with Modular Construction, There are critical issues relating to insolvency risk associated with modular construction owing to a substantial proportion of a project's turnover resting with one sub-contractor. Bespoke design associated with modular construction can add to the risk and increase costs and potential delays. Bond packages including parent company guarantees may be used to address this risk.

Despite the best efforts of pioneer businesses in the premanufactured sector, there is not yet a successful business case established for this construction approach. Like many new products and process innovators, compelling empirical evidence for the end-demand market which could lead to large-scale adoption of this approach is lacking. Viewed broadly quantitatively and qualitatively against the traditional site-based labour-intensive approaches, including comparisons of variables such as speed, certainty, quality, smart technology possibilities, capex, and opex, there is a lack of robust quantifiable evidence to justify a need for pre-manufactured construction (Assaad et al.,2022). This reduces its appeal to both Clients and Main Contractors as the benefits case for pre-manufactured construction is difficult to demonstrate. The evidence from the review in this paper does not suggest the superiority of any of the identified constraints. Whilst there is some evidence that cost-related factors appear to be the most important in relation to residential developments, additional work is required to establish whether this applies to the rest of the industry. Some additional investigation of the value of offsite at project, portfolio, and asset whole-life levels will also be beneficial in seeking to address the constraints which hinder the uptake of offsite construction approaches in the construction industry.

5. Conclusions and recommendations

This paper asserts that despite the acknowledged and obvious benefits associated with offsite construction approaches, the uptake continues to be low globally. Some of the common hindrances relating to cost, quality, risk, demand, and capacity are identified in this paper. In addition to these, there is limited quantitative evidence available to show that offsite manufactured assets do offer whole-of-life cost savings as compared with onsite constructed assets. Owing to the industry's focus on reducing total costs (totex), it will be helpful to the industry to find data sets to demonstrate the whole life value offsite. This will provide credible evidence for the value of offsite at project, portfolio, and asset whole-life levels.

References have been made in this paper to previous studies which suggest excess capacity by offsite manufacturers. In the absence of reliable recent data on manufacturer capacity, it is recommended that further study be undertaken into UK offsite manufacturer capacity to determine the true state of producer capacity to cope with increased demand for offsite construction inputs. As reported in KPMG (2016), "a clearer picture of UK offsite factory capacity and utilisation is needed to help clients and investors better exploit latent capacity in the market". Also, the issue of the sub-contract terms in the context of the main contract with which the contractor has to comply has to be investigated and interrogated to find the main contractor's view of this. Finally, whilst much of the existing literature, especially industry reports focus on the use of offsite methods in residential developments, some additional work on other uses, for example in high-rise developments will be beneficial.

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