# PREFABRICATION IN THE UK HOUSING CONSTRUCTION INDUSTRY

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**Abstract:** This paper aims to explore how prefabricated methods of construction could address housing shortages in the UK. The available literature is reviewed to evaluate current conditions of housing as well as prefabricated methods of construction in the UK. Advantages and limitations of prefabrication are investigated and discussed in relation to the current conditions. Interviews are also conducted as well as case studies in order to understand the challenges and to provide first hand information on current industry practises in the UK housing construction industry. Findings indicate that although offsite construction is widely known and acknowledged, there is little encouragement and incentives to maximise the use of prefabrication in the UK. Extra costs, larger lead time and engineering issues are found to be the key factors preventing the innovative *processes of prefabricated construction in the UK's reside*ntial sector.

**Keywords:** Prefabrication, Dwellings, Offsite Construction, Challenges

## 1 Introduction

The current challenges facing the housing industry are creating an indisputable pressure to innovate and change the way in which house builders are constructing and operating (Tam et al 2007). With an increasing population, one challenge the UK construction industry is facing is trying to meet the rising demands in dwellings (Cheshire &Sheppard 1998). Not only is demand for housing increasing, but it is having a detrimental effect on the price of properties with many observers claiming that we are in the midst of an 'affordable housing crisis' (Feldman 2002).

Alongside an increasing population that is resulting in a high housing demand, the UK construction industry is currently facing a shortage of skilled labour (Dainty et al 2005). The industry's continued growth in output, coupled with its unpopularity as a career choice has put extreme pressure on its labour market capacity (Dainty et al 2005).

One other challenge the UK construction industry is facing is the increasing pressure to become more environmentally friendly. This issue is being further magnified due to the waste generation traditional construction methods create (Jallion et al 2009).

This pernicious state of flux is being experienced nationwide and the need to resolve the challenges that the UK housing industry is experiencing has prompted the interest of academics and professionals to research into potential solutions.

Prefabrication, commonly known as modular construction, offsite construction and modern methods of construction (MMC), is an act of manufacturing a structure or a component in a factory under controlled conditions (Azman et al 2012). The completed feature, which would have normally been built onsite, is then transported to the required location (Ross et al 2006).

Post war building had been identified early on by the British government as challenging (Phillipson 2001) and the shortage of housing after World War II was emphasised once military personnel returned home (Bosch & Philips 2003). Various techniques had been explored to find a main alternative to bricklaying (Phillipson 2001) which led to the phenomenon that was known as the Modern Movement. The Modern Movement raised the argument that mass production was needed in order to cope with the massive social demand (Hashemi 2013).

The 1960's had been the decade where high rise buildings were being constructed with a heavy reliance on prefabrication (Finnimore 1989). The nature of prefabricated components, in being similar, created friction and disagreements within society (Hashemi 2013). In addition to the aesthetic monotonous controversy, a gas explosion at the infamous Ronan Point, a high-rise building that used extensive precast panels, caused the 18th floor of a 22-story building to collapse (Molkov 1999; Lovell & Smith 2010; Knaack et al 2012). Despite the cause of the explosion not being directly related to the utilisation of prefabrication (prefab), the image of offsite construction had been substantially damaged which ended its accelerated use (Hashemi 2013).

Arguably, the use of prefabrication offers several key advantages over traditional construction techniques. Due to the nature of prefabrication where time savings (Wong et al 2003), increased cost predictability and value for money is enhanced (Hashemi 2013), supporters are of the opinion that the deficit of housing may be met by offsite construction (Steinberg 2007).

It is also thought that prefabrication can reach sustainable targets due to factories being able to control energy and emissions more easily than construction sites (Gibb 2009) as well as managing sustainability targets due a reduction in construction waste produced (Poon 2007; Tam et al 2007; Jaillon et al 2009; Lu & Yuan 2013). Moreover, as a by-product of utilising offsite construction, it is widely thought that a reduction in labour pressure may be obtained due to requiring less to achieve similar on-site results (Jaillon et al 2009).

Piroozfar et al. (2009) conducted a study where two similar buildings were compared in terms of performance and age, where one had been constructed using a modular-based system and the other building utilised established methods of construction. Under similar uses, it was found that energy consumption of the building that utilised prefabricated elements was 13% better than the benchmark for the good practice, whereas the energy consumption of the building built with traditional methods of construction was just over 6% better (Piroozfar et al. 2009).

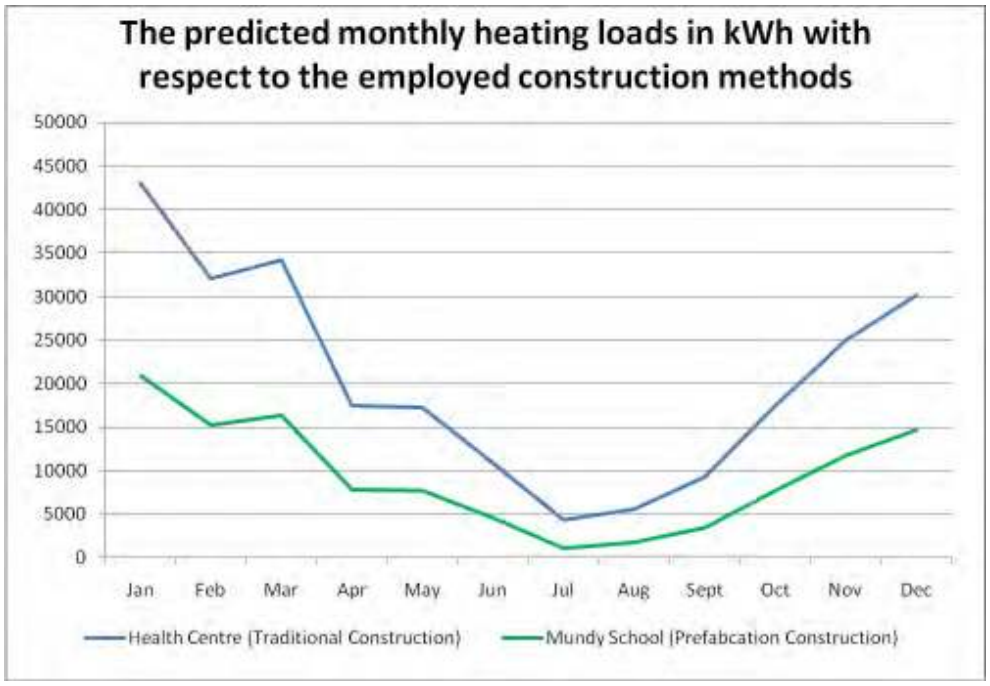


**Figure 1: The predicted monthly heating loads in kWh with respect to the employed construction methods; Adapted from (Piroozfar et al. 2009).**

Whilst the potential benefits of adopting prefabrication in the construction industry are highly discussed, barriers that may be encountered when utilising the innovative constructing method are affecting the uptake in the UK housing construction industry. The potential of limiting design flexibility and customisation (Hashemi & Hadjri 2013) in addition to the steep perceived costs to implement are some of the said barriers that the industry is encountering (Lovell & Smith 2010). Furthermore, a fear of change (Phillipson 2001), engineering obstacles, such as embedding mechanical and electrical (M&E) services in cast in-situ concrete (Rashid 2009) and a larger lead time, may provide challenging to the UK housing industry (Tam et al 2007).

Even though continuous, incremental innovation has not been important for the average UK house builder's continuity, a much more pro-active approach to innovation will be needed in the future in order to stay competitive (Barlow 1999). It is not known what the

future for prefabrication in the UK holds, but the number, location and capacity of plants for the production of elements must be considered thoroughly in order for prefab to be successfully implemented (Warszawski & Ishai 1982).

A thorough investigation is required in the area of offsite construction in the UK as the literature surrounding this topic is limited on current views and execution of the practice. A questionnaire had been designed to evaluate the current situation of MMC and the views of practising construction professionals in UK housing construction industry. Case studies had also been conducted in order to provide information on current industry practises. The questionnaire results reveal several key barriers which are hindering the adoption of the innovative solution that prefabrication presents in the United Kingdom. The case study results identify key reasons as to why prefab is currently being integrated by certain house builders into their traditional house building process.

## 2 Methodology

Secondary data was collected through the analysis of a range of sources, including conference papers, reports, journal articles and books in order to carry out a detailed evaluation on the current content that is available. Primary data was also collected through the use of questionnaires. The questionnaire aimed to recognise the opinions of house constructing practitioners on prefabrication in the construction industry.

A pilot study was conducted to evaluate the time required and to ensure requirements for each question had been met. The questionnaire was distributed amongst targeted individuals from medium/large house builders. It was assumed that medium and large house builder would have more access to resources allowing them to deal with large scale projects and thus, may share more insight. Professions that had been targeted included projects managers, construction managers and quantity surveyors which had been chosen in order to represent the key job roles that a UK house builder of a substantial size would hold. The questionnaire consisted of four key sections and was primarily made up of three question types;

- Dichotomous, whereby the question offers a ‘yes’ or a ‘no’
- Multiple choice whereby the question offers three or more choices
- Likert scale where the respondent shows the amount of agreement or disagreement (Strongly agree to strongly disagree).

Whereas Section A aimed to gauge the participant’s background including their industry experience, profession, gender and their companies’ capabilities, the subsequent questionnaire consisted of three following sections that had been defined as key criteria that had been based on the findings of similar research questionnaires. Section B captured the level of awareness that practitioners have of prefabrication in the construction industry; Section C aimed to capture the views and opinions of practitioners in the construction industry on the application and practise of prefabrication and Section D had been designed to explore the views and opinions regarding the future of prefabrication in the housing construction industry.

An investigation of three case studies were also been conducted. The first case study utilised prefabricated roof panels. The second and third case study reviewed the construction of dwellings that had been constructed at BRE’s Innovation Village, an innovation park rich in Modern Methods of Construction (MMC) located at Watford, UK.

## 2.1 2.1 Questionnaire distribution and analysis

Questionnaires were sent to 174 specific professionals who had a period of 31 days to return the completed questionnaire. Out of the questionnaires sent, there were 54 respondents which equates to a 31% response rate. The majority of those were project managers (20%), construction managers (19%) and quantity surveyors (13%). Only two directors (4%) and three general managers (6%) responded to the questionnaire. Out of the total respondents, 56% were male and 44% were female.

When it came to industry experience, the highest amount of respondents (20%) had between 7 and 10 years and 17% of respondents had 15 years or more industry experience. 6% had 1 year or less and a further 6% had between 1 and 2 years. A total of 4 respondents (7%) worked for a company that constructed up to 2,000 houses in the previous year, 13 respondents (24%) selected 'between 7,500 to 10,000' and the most common option selected had been between 10,000 to 15,000. Statistical Package for Social Sciences (SPSS) had been used to analyse the data and to examine the significance of the results. The results in over 94% of cases were statistically significant to $P < 0.05$. The results have been rounded to the nearest 1%.

# 3 Results of Questionnaire

Whereas Section B (3.1) explores the level of awareness that practitioners have of prefabrication in the construction industry, Section C (3.2) aims to capture the views and opinions on the application and practise of prefabrication in the construction industry. Section D (3.3) aims to explore the views and opinions regarding the future of prefabrication in the house construction industry.

## 3.1 3.1 Prefabrication Awareness

All respondents, to a certain extent, had considered themselves as aware of prefabrication in the construction industry. When it comes to the most advantageous aspects of prefab, the respondents considered time improvements and the potential of minimising site-based accidents came out on top with an average weighted score of 3.8. When asked which advantage they thought would be the most beneficial to their organisation at this moment in time, time improvements was ranked as the highest benefit (28%).

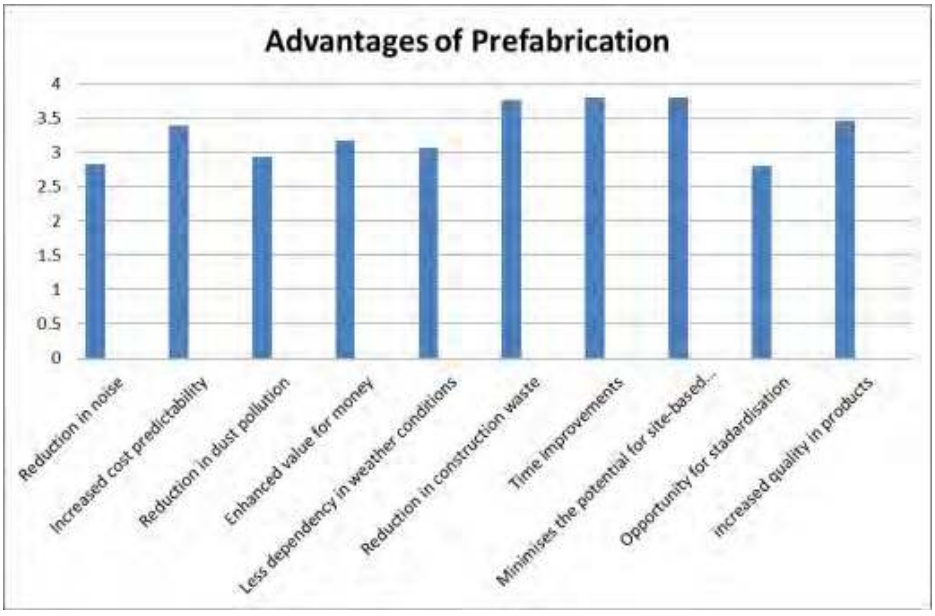


**Figure 2: Advantages of prefabrication.**

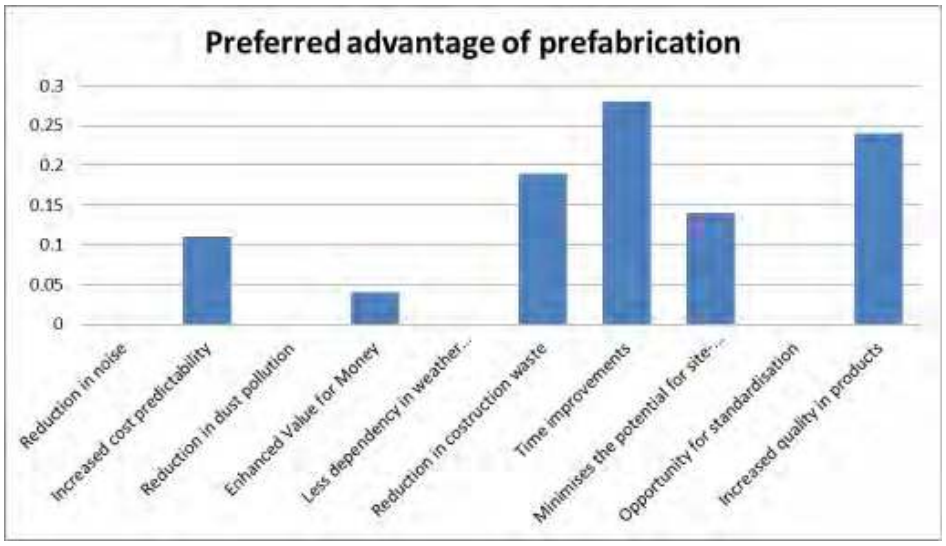


**Figure 3: Preferred advantage of prefabrication (%).**

## 3.2 3.2 Views and Awareness

As a whole, responses indicated that prefab was seen as beneficial to the overall construction industry however, the majority of respondents (35%) said that they never suggest using prefabrication and a further 28% of respondents selected rarely. The majority were of the opinion that more could be done to apply prefab in projects that they worked on (98%) whereas only 2% of respondents had been of the opposite opinion.

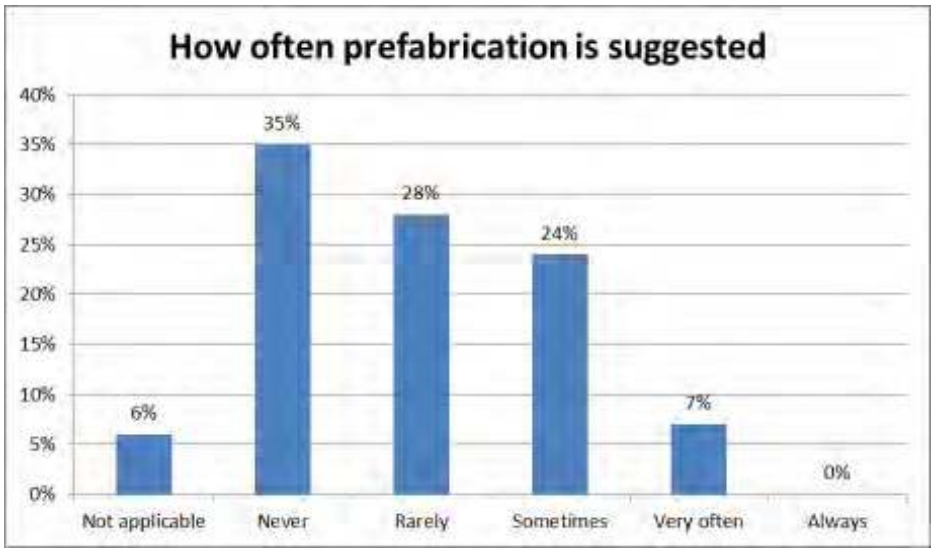


**Figure 4: How often respondents suggest using prefabrication.**

## 3.3 3.3 Future of Prefabrication

When it came to denote the degree to what they believed were the biggest barriers that prefab in the in the UK construction industry was facing, extra costs has been rated the highest with an average weighting of 3.91. Other factors included potential limitations in site space (2.8) and engineering issues (3.69), with the lowest rated factor being no demand for prefab (2.59). There had been a 100% agreement that more could be done to raise awareness in regards to prefabrication in the construction industry and the majority

of respondents said that government subsidies would be the most likely incentive to increase prefab in the UK house building industry in the shortest time possible.

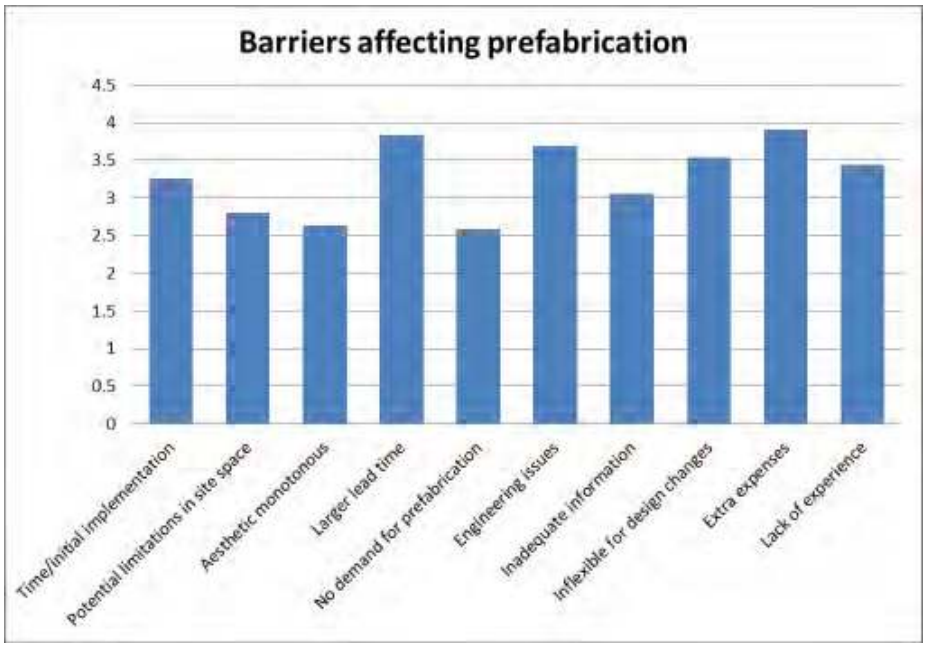


**Figure 5: Barriers of prefabrication.**

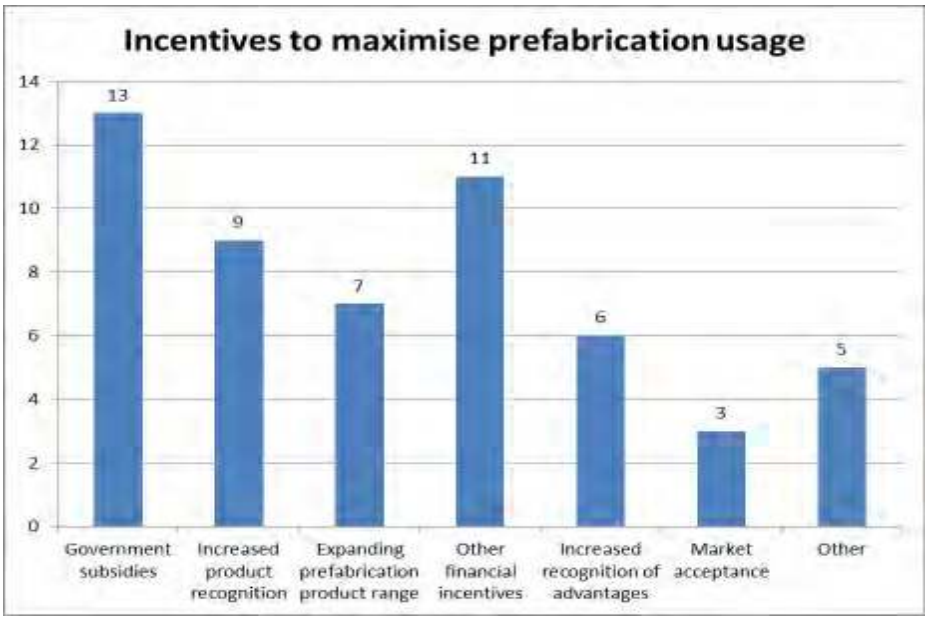


**Figure 6: Incentives that would increase the use of prefabrication in the house building industry.**

## 4 Case Studies

### 4.1 Barratt Homes

With the increasing demand in housing, Barratt homes, one of the largest residential property development companies in the UK, have explored many prefabrication options. One system that has been adopted into Barratt's traditional housing construction is the RoofSpace I-Roof system whereby panelised roofing panels replaces the traditional construction process.

**Figure 7: Dwelling awaiting roof tiles.**

The RoofSpace I-Roof™ System is an innovative and sustainable timber engineered panelised roof system. It encapsulates the roof space of dwellings in order to provide habitable and cost efficient living spaces. There have been several other developments that Barratt have constructed in the surrounding areas of Ashford, the majority of which have utilised the I-Roof system extensively.

Barratt homes started using the I-Roof system around 7 years ago in order to design steels out of certain roof types. The steels posed a steep health and safety risk as they would occasionally be dislodged by adverse weather conditions. Furthermore, the steels would often account for many reported minor injustices such as cuts. Other safety benefits include a reduction in working at height and the reduced risk of a gable block work collapsing (Cook 2016).

**Figure 8: Tradesman installing one of the prefabricated roof panels.**

Panels are fixed down to the wall plate, which is bedded in mortar and fixed to the block work using L-shaped restraining straps. Potential savings of days and even weeks can be made in a typical build programme. Barratt now installs over 1000 panelised roof systems per year (Cook 2016).

## 4.2 4.2 Hanson Ecohouse

Hanson Ecohouse, situated at BRE's Innovation Park, is home to some of the world's most sustainable buildings. Built in 2007, the Hanson Ecohouse is a detached, 117 square metre (sq m) two story house, designed to showcase the latest developments in masonry construction and smart technology. It was the first of its kind to achieve a Code Level 4 under the Code for Sustainable Homes in which offsite construction played a significant role (McCann 2016).

**Figure 9: Hanson Ecohouse.**

The dwelling makes extensive use of prefabricated walls, a composite ground floor system and a precast concrete staircase. High thermal mass levels have been achieved with prefabricated elements which will allow the building to store heat during warm periods and release it during cooler spells. The energy saved by the thermal mass in a masonry house can help significantly to reduce the carbon dioxide emissions over the life of the building (McCann 2016).

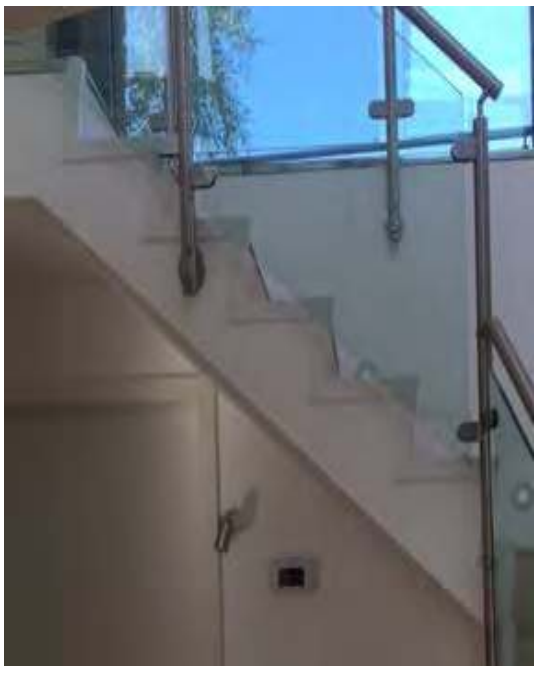

**Figure 10: Precast Staircase in the Hanson Ecohouse.**

The structural walls of Hanson Ecohouse have been constructed using the Hanson's quick build walling system. The external walling system comprises of pre-insulated and pre-finished brick and cavity wall panels. Once the panels had been factory made and delivered, a crane had been used to position them into place. Ground panels were then mortar jointed directly onto preformed foundation walls. The use of prefabricated components led to the timely completion of the dwelling (McCann 2016).

### 4.3 4.3 Sigma Rexel House

The Sigma Rexel house comprises of two separate dwellings and was the first house in the UK to achieve a Code Level 5 under the Code for Sustainable Homes. The design addressed the need for high density living with 4 levels having been designed over the size of a large three story house. This resulted in minimising the building's foot print and maximising affordability (McCann 2016).

**Figure 11: Sigma Rexel house.**

Similar to Hanson's Ecohouse, the Sigma Rexel house utilised offsite construction extensively in order to reach a high level of sustainability whereby a 100% reduction in carbon dioxide emissions have been achieved. The panelised system employed had factory fitted insulation, air membrane and service cavity batons ready from the supplier. The engineered timber floor had been factory pre-made with pre-fitted decking installed. Other elements that had been factory made included the foundation piles, precast ground beams and the pre-insulated roof cassette system (McCann 2016).

**Figure 12: The kitchen in the Sigma Rexel house.**

In just 10 working days, the main superstructure had been made wind and water tight and took a total of 10 weeks to complete. The fast build time can be directly related to the extensive use of prefabricated components (McCann 2016).

## 5 Discussions

The results of the questionnaire has identified key issues that need to be highlighted before prefabrication can be established as a common form of construction in the UK housing construction industry. According to the results, the most advantageous aspect of prefabrication is a reduction in potential site-based accidents and time improvements. Previous studies (Samuelsson Brown et al 2003; Goodier & Gibb 2007; Hashemi 2015) have also found that respondents to a similar question rated a lower construction time as the most important factor that prefabrication brings. In the Sigma Rexel house and Hanson Ecohouse, the use of prefabricated components have been linked to the quick erection, further supporting the perception that prefabrication allows for time advantages when compared to conventional construction techniques.

Even though previous studies have not identified the potential for minimising site-based accidents as a main reason for utilising prefab, the findings of this research show that professionals working in the construction industry are becoming more health and safety conscious and that the overall opinions in construction professionals is changing. This is further supported by Barratt Homes having introduced prefab to their traditional house building process in order to minimise health and safety risks (Cook 2016). Transferring much of the construction programme from an open site to a controlled factory setting may greatly reduce on-site worker activity and the associated risks of site-based accidents (Blismas et al 2006). The opportunity for standardisation came in last place (9th). Professionals in the construction industry need to recognise the importance of standardisation as it is directly related to the overall costs of prefabricated components, therefore by increasing the standardisation of products will lead to an enhanced value for money.

Even though prefab is widely recognised in the construction industry with all respondents being aware to a certain extent, most respondents stated that they never suggest using prefab in place of traditional methods. The lack of suggestion might be due to the respondents being worried of negative criticism by suggesting an unconventional method of construction.

Higher capital costs, whether perceived or real, had been considered as the most significant barrier that prefabrication is currently facing in the construction industry. The findings of previous questionnaire surveys (Goodier & Gibb 2007; Pan et al 2008; Jallion & Poon 2008) further supported that increased costs had been considered as the biggest barrier affecting prefab. Costs of integrating innovative processes such as offsite construction to the UK housing industry may lend costly (Lovell & Smith 2010) and with it being the highest rated factor suggests that the industry is more fixated on costs rather than on other potential benefits prefab may bring. The construction industry should also focus more on important factors that need addressing such as achieving sustainability targets and meeting housing demands in order to progress. No demand for prefabrication came in last which further emphasises that there is a need for prefabrication in the industry however there is resistance to shift.

There was a 100% agreement that more could be done to raise awareness in regards to prefabrication in the construction industry and the majority of respondents believed that government subsidies would be the quickest way in which the uptake for prefab would increase within UK housing construction industry. Moreover, 20% of respondents were of the opinion that other forms of financial incentives were required in order to increase the use of prefab. These two factors are both financially orientated and tie in with previous findings of this research, that the industry is financially driven.

The results of the questionnaire indicate that many respondents are of the opinion that the use of prefab would increase in the future, however, several respondents mentioned perceived hindrances associated with prefab needed addressing before there is an increase in uptake with one respondent mentioning that lead times need to be significantly lowered. Construction is in a period of rapid cultural change accompanied by the introduction of new technologies and new ways of organising construction activities (Agapiou et al 1995). The future of offsite construction is dependent on many factors, not least of which is a better understanding of the construction process and its associated costs (Blismas & Wakefield 2009).

## 6 Conclusion

Considering the three main challenges that the UK is currently experiencing; skilled labour shortage; a housing shortfall and sustainability targets, the use of offsite methods of construction would potentially improve the current situation. However, the results of this study have suggested that prefabrication has many barriers to overcome before it can be considered as a mainstream construction technique, including costs, addressing lead times and the need to retain a degree of flexibility for design changes.

In order to improve current conditions and to increase housing production to meet demands, there is a prerequisite for cultural change in the construction industry, one that is widely recognised for the non-collaborative, blame culture and conservatism which hinders diffusion of innovation. In order to drive the necessary cultural change, there is a requirement for more dedication on behalf of construction workers alongside a degree of commitment from top management. There also needs to be commitment to remediate and solve the current issues that the industry is experiencing and a more open and proactive

approach in attempting to modify the traditional form of construction for the better. Further research may seek to conduct interviews with a wide range of stakeholders which could lead to identifying new emerging issues and trends. Visiting well-established prefabrication manufacturing sites in the UK would also help to understand the available offsite products as well as investigate the barriers from the manufacturers' perspective.

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