The potential for prefabrication in UK Housing to improve sustainability

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1. INTRODUCTION

Off-site, factory production of dwellings has the potential to lead to significant improvements in both the quality and speed of construction compared to traditional site-based construction. The technical benefits include increased speed of production, reduced levels of defects and waste, greater efficiency in the production process, and improved environmental performance. These are all generated as a direct result of moving more of the construction process from the building site, where efficiency is poor and management difficult, into the relative safety of factory conditions, where efficiency and control can be better managed. This can also lead to social benefits including improvements in health and safety, more stable employment and investment into machinery and development of skills. Greater stability in the manufacturing process also generates potential economic benefits.

All of these contribute to environmental, economic and social benefits of sustainability. This paper will review the sustainability benefits of prefabrication, and look at the various alternative ways that prefabricated building systems are beginning to have an impact on the way residential buildings are constructed in the UK.

2. UK CONSTRUCTION

In the UK, government predictions suggest that 3.8 million additional new dwellings will be required over the next 25 years. Current replacement rates are minimal, with most new housing adding to the stock rather than replacing old, outdated housing. Within the social housing sector it is estimated that from 2000 to 2016 one million new dwellings will be required. These will be mainly in the form of high-density terraced houses and purpose built flats. This presents a significant challenge to the UK construction supply chain with its diminishing labour force and increased business performance demands. Furthermore, client requirements for higher building standards and the industry’s increasing regulatory improvements, particularly in thermal and acoustic performance, and health and safety issues are pushing the industry to reconsider on-site methods of construction and to investigate other ways of building homes.

However, until recently prefabrication in housing in the UK has been associated with a reduction in flexibility and choice for the designer, client and end user, and with higher costs. Market resistance has prevented significant uptake of such technology in the UK despite examples here and from abroad illustrating its technical feasibility.

To address these issues, government backed reports such as “Constructing the Team” (Latham) and “Rethinking Construction” (Egan) have clearly identified that the construction
industry must change its way of working if it is to prosper and serve the needs of society. Construction must address market demands of improved efficiency, better quality, faster construction and better cost control. Other pressures to change the way we build have come from increased concerns about the impact of the construction process on the environment and local communities and the chronic skills shortages of site skilled labour. This has led clients to take increasing account of the sustainability impacts of how we build, as well as how we operate and maintain our buildings. It has led to a greater interest in off-site manufacturing technologies and house builders are currently investigating a variety of innovative ways of building dwellings. Recent reports (CRISP) have identified considerable areas of overlap between the agenda of improved industry efficiency through prefabrication and partnering, and the sustainability agenda.

3. OFF-SITE MANUFACTURING SYSTEMS

In the UK there are three principal approaches to off-site production of buildings using lightweight construction currently being used. These are discussed below:

3.1 Volumetric systems

Three dimensional units are manufactured in the factory with a high degree of services, internal finishes and fit-out installed in controlled, factory conditions prior to transportation to site.

This has many benefits including improved quality, reduced defects and snagging on-site, increased speed of construction on site, better working conditions, increased predictability and efficiency in the production process. This approach is particularly suited to highly serviced areas such as kitchens and bathrooms, which have a high added value, and cause disruption and delays on site, but may be less appropriate for other rooms which have less internal fit-out. For this reason some recent high profile projects have used volumetric bathroom pods in conventional residential buildings.

Volumetric systems have the disadvantage that each unit has to be transported separately, and the maximum size of the unit is determined by the practical problems associated with transportation by road. The factories operate most efficiently when a large number of similar units are made to the same dimensions. Both of these factors work to reduce flexibility in layout and design. For these reasons most volumetric construction in the UK to date has been in the hotel, hospital and fast food chain sectors, where repetition of units is possible. In addition, because the units have to be self supporting and are craned into place on site, the strength and rigidity must be sufficient to allow this process to occur without damaging the unit. The strength requirements for lifting operations may exceed those for in-use service, thus the structure may be over-designed for its end-use, leading to wastage of materials.

3.2 Panellised systems

Flat panel units are produced in a factory, and fixed together on site to produce the three dimensional structure. Services, windows and doors, internal wall finishes, and external claddings can potentially be installed in the factory but in most current systems in the UK the services installation, external cladding and internal finishing occurs on site.

Panellised systems are more flexible and can more easily accommodate variations in unit plan and detail design than volumetric systems. Spaces such as bedrooms and living spaces lend themselves to panel construction systems, providing greater choice to the client and designer,
with few restrictions on room size and layout. Furthermore, panellised systems have the advantage that, because they can be stacked flat, more of the structure can be transported in one journey. However, the levels of finish and services which it is practical to install into panels prior to shipping to site are reduced compared to volumetric. This leads to more work on site and requires further deliveries of other materials, components and labour to site. This may be appropriate for plain walling but would be a disadvantage for highly serviced areas such as kitchens and bathrooms. Also, there is a greater likelihood of damage to the finishes applied to the panel during transportation or on site.

3.3 Hybrid (semi-volumetric) systems
A third option which maximises the benefits of prefabrication is to combine the benefits of volumetric and panel construction by using volumetric units for the highly serviced areas such as kitchens and bathrooms and constructing the remainder of the dwelling using panels. This offers the opportunity of bringing together the benefits of each system, and address the issues of providing flexibility and consumer choice.

Such an approach may combine the benefits of economies of scale and the economies of scope, utilising mass production, factory production and standardisation to provide flexibility of options offering customisation. A kit of parts can be used to provide flexibility yet maintain the benefits of standardisation.

4. SUSTAINABILITY BENEFITS
Prefabrication can address a wide variety of sustainability issues. Some of these are discussed below:

4.1 Reduced local impacts
One of the key features of prefabrication is that much of the process is removed from the site to controlled factory conditions. This reduces the amount of time spent on site, which leads to reduced impacts on the locality. Experience in the UK shows that prefabricated hotel buildings can be constructed on site in less than half the time of a traditionally built hotel of a similar size. This means that the locality around the site is disrupted for a shorter period reducing noise, pollution emissions and local traffic disruption. Furthermore, the lightweight nature of the buildings can often result in smaller foundations and therefore less groundworks, also reducing local disruption as well as reducing the volume of materials used in the groundworks.
From a financial point of view the shorter construction period allows a quicker return on investment by the client, and reduced overhead costs.

4.2 Reduced levels of defects

Achieving quality construction is often very problematic in difficult, exposed site conditions. Factory based activities allow better quality management, with testing and checking procedures more easily implemented. For example, volumetric units can have electrical and water installations fully tested prior to leaving the factory. General experience in the UK suggests that far less call backs are necessary to make good defects after completion for buildings using a lot of prefabrication. This is a significant cost and efficiency benefit to the builder and leads to satisfied customers. It also improves efficiency and reduces wastage of resources.

4.3 Less waste in manufacture

Waste from construction is one of the principle waste streams in the UK leading to at least 70 million tonnes of waste per annum. Manufacture in a factory allows far better management of the waste stream with more efficient use of materials and ordering of exact amounts of material, more careful storage, and the possibility of design to suite standard sizes. In addition any waste that occurs can be more easily collected and reused or recycled. Many manufacturers of components have recycling facilities installed, as this reduces the costs of disposal of waste. There is further potential for reducing waste when using prefabrication if the designer is prepared to co-ordinate sizes so that materials such as timber and gypsum sheets are used in their standard sizes without generating many offcuts.

Assembly of prefabricated components on site should generate little waste as the components come to site pre-engineered to assemble together.

4.4 Health and safety benefits

Construction work on site can be a dangerous activity and leads to significant numbers of casualties and fatalities. More demanding health and safety requirements are pushing many builders to consider off-site manufacturing techniques. This allows much of the process to be carried out in more controlled and comfortable factory conditions where safety requirements can be more easily met and policed, and healthy and comfortable working conditions are more readily maintained. The use of scaffolding is a particular concern, and some schemes in the UK have tried to eliminate the need for scaffolding completely by integrating claddings in the factory. Conversely the use of heavy lifting equipment too locate the prefabricated components on site requires careful management.

4.5 Improved environmental performance of the final product

Thermal and acoustic performance is very dependent on the quality of workmanship and supervision. The correct installation of the elements of the fabric, in particular insulation materials and air barriers are important to the performance of the building in use. Factory manufacture allows operatives to be better trained and supervised in these tasks, and allows regular checking and testing of performance. Problems such as omitted insulation and badly fitted air barriers are less likely to occur. Reports from North America suggest that direct comparisons show higher thermal performance standards for homes that use off-site manufacturing techniques.
4.6 Social benefits from improved working conditions

Employment at a factory manufacturing prefabricated building component is generally more stable and long-term than site based employment, which is intrinsically transient. As a result, factory based employers are generally more willing to invest in training for their workforce. Furthermore, to function efficiently prefabrication requires high levels of skill and flexibility in the workforce. This necessitates greater training by employers.

Building sites are temporary employment locations, so they generally offer little long-term amenities for the local community. Manufacturers in factories are often closely linked with the local community, with much of the workforce coming from the locality. They provide a long-term economic and often social service for the community. Many manufacturers of prefabricated modular or panel units in the UK are well established in particular locations and have developed a highly trained local workforce, and strong links with the local community.

4.7 Greater efficiency in the use of resources, both materials and labour

Building sites are notorious in the poor efficiency in the use of labour and materials. Studies in the UK have shown that site based activity has a considerably lower efficiency in the use of labour compared to factory based activities. In some cases the useful activity on site can be below 50% of full potential. Furthermore, it is estimated the between 13% and 18% of materials delivered to UK construction sites is wasted and never used properly. Manufacture in the factory allows higher levels of efficiency to be achieved.

In addition, volumetric construction using prefabricated pods or modules allows building to be potentially dismantled and the modules reused at a different location. Modular hotels in the UK have been dismantled and removed to a different location when found to be uneconomic at their original site. Similarly, many volumetric buildings are used as temporary buildings and removed for reuse when no longer necessary. Thus, the technology for reuse is established. Many of the materials used in this type of construction such as the steel framing can also be extracted for recycling at the end of the life of the module. This is made easier by the lightweight, dry construction methods that are generally used. This is likely to become more significant in the future when EEC legislation about producer responsibility encompasses the construction industry.

4.8 Transport

Transport is a complex issue, and monitoring of transport patterns relating to construction sites is difficult. In general, prefabrication leads to a reduction in the numbers of deliveries to site compared to traditional construction methods. Some monitoring of a site in London suggested that deliveries to site were reduced by up to 90% for a volumetric building compared to a similar building nearby. However, these are generally large vehicle deliveries often coming considerable distances from the factory. In addition, the shorter period on site and the nature of the work means that less labour is required on site and for a shorter period. Thus, in general it is likely that a well managed site using prefabricated components can significantly reduce the impact of transport.

Conversely the additional transport movements related to the factory should be considered. However, the workforce in a factory is more likely to be local than at a building site, and thus will travel shorter distances, and is more likely to use public transport, where possible.
Secondly, material deliveries to a factory can be planned so that full loads are always delivered, and local suppliers can be used.

5. CONCLUSIONS
The objectives of sustainability and the 'Rethinking Construction' agenda of improving efficiency in construction overlap in several areas, notably waste minimisation, process integration, a commitment to people and a quality driven agenda. Prefabrication offers an opportunity to address both these agendas, and improve both efficiency and sustainability. However, the industry has much to learn to fulfill the potential of this technology. The following points should be considered:

1. There is an increasing interest in prefabrication in the UK house building industry. This is partly due to the effect of the report of the Construction task Force "Rethinking Construction" published in 1998. Furthermore, house builders are beginning to realise that there is a need to improve standards and that new regulatory requirements such as the changes to Part L of the Building Regulations dealing with energy efficiency will be more easy to satisfied by increasing the amount of off-site manufacture.

2. There is a well established sector of the construction industry manufacturing volumetric units for hotel construction, key worker accommodation, the education sector and budget restaurants. The economics of this type of construction relies on repeatable units so that large production runs can be set up. A figure of 40 repeatable units (of similar size and layout) is sometimes quoted as a minimum number required for such systems to be cost competitive. Another sector of the industry provides a wide range of panels mainly for housing units.

3. The volumetric manufacturers have developed technical systems and construction processes to maximise the benefits of this type of construction. The management of the construction process has been identified as a particularly important area, and the interaction of the prefabricated components with site processes such as foundations, service connections and cladding are critical.

4. Health and safety issues are driving many changes in approach. The elimination of scaffolding is seen as a desirable objective.

5. Many of the companies developing off-site manufactured systems are investigating options for alternative claddings to traditional brickwork. The perceived market preference for brickwork is seen by many as a potential obstacle for wider adoption of prefabricated systems. Alternative cladding systems are being developed with improved detailing. Many UK schemes using prefabrication also use alternative cladding systems such as cedar boarding, polymer based renders or rainscreen cladding.

6. When considering the technical issues of off-site manufacture it is essential to also considered the process of manufacture and assembly. Technical decisions can lead to process problems, and so both must be considered together.

6. REFERENCES
