Off Site Production and Benefits in the UK Construction Industry: Theoretical Approach

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Abstract

The growing interest in sustainable construction, rapid technological improvements and increasing labour costs should provide opportunities for Off Site Production (OSP) to serve sustainable projects. However, OSP value has often been limited because the benefits have not been fully recognised and well defined in the construction industry. In light of this, the paper set to critically review in details, the benefits of OSP towards making case for its application in the UK construction industry. The aim is to encourage the industry to take full advantage of potential Off Site Production benefits towards achieving the overall project goals regarding cost, quality, time, health and safety, and sustainability issues.

Review of extant literature of current theories and issues surrounding the term '***Offsite Production'*** forms the basic methodology for the research. It is found that, some techniques in construction just supplemented the more traditional methods rather than providing the answer to the industry's problems. OSP as a common technique in the industry if employed will effectively enable process standardisation, minimise labour cost, and material waste as well as improve quality control within the construction industry.

Keywords: construction industry, off site production, and sustainability

Introduction

Every project within the construction industry usually has its own targets and the desired outcomes that it aims to achieve. These are most of the time influenced by a wide range of factors, such as the clients and contractors needs, the current economic climate, or the level of demand from the end user. Despite these varying influences, three key issues that are usually significant to all projects which form the three corners of the classic triangle are**: time, cost and quality** (Gibb, 1999).

These three factors had been the major basis for construction management, education and training for many years, and still remain the key influences to majority and large construction projects. However, only two out of these three key issues can be achieved in one particular construction project and is usually at the expense of the third (Brinkley, 2002); 'You can have a good, cheap job but it won't be quick or a cheap and quick job that won't be any good' (Brinkley, 2002).

Conversely, some researchers (Neale et al., 1993, Gibb, 1999, Phillipson, 2001, Song et al., 2005) disagreed with this phenomenon that only two out of the mentioned three key issues in the model could be achieved in one particular construction project. Contrary to Brinkley (2002), they all identified the fact that OSP has the potential to provide the construction

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industry with the opportunity to benefit from all the three classic triangle factors. Their principle is that off site process has the ability to provide higher quality products, whilst building to optimum costs, and at the same time provide quicker construction times.

It is due to these conflicting opinions coupled with the growing interest in sustainable construction, rapid technological improvements and increasing labour costs that this paper seeks to analyze each of the three components along with some other benefits that can be achieved within a project in relation to sustainability within the construction industry. This is to justify OSP application, its value and benefits as good investment towards future developments and sustainability in the UK construction Industry.

The Major Benefits of Offsite Production

Offsite technologies offer potential for reductions in cost, time, defects, health and safety risks, environmental impacts and a consequent increase in predictability, whole life performance and profits (Parry et al., 2003, Sparksman et al., 1999, Gibb, 1999, Venables et al., 2004, Build-offsite, 2005, Pan et al., 2007). Out of this lot, the three distinct benefits of using Offsite production on any major construction works 'time saving benefits, reducing costs and enhanced high quality of final building' are discussed in this section as the major benefits of OSP .

Time

'***Time'*** is the time taken to cover or the number of weeks allowed for work on a building contract (MacLean and Scott, 1995). It usually starts on the date of site possession and ends at the date of handover. Time has been widely reported as being the main benefit available to construction projects when using OSP (Baba, 2009). This is because significant timesavings can be achieved in both the onsite program and the overall project duration. These reductions are possible in a number of different ways, but the most common method is arguably achieved by overlapping the offsite and on site activities (Baba, 2009). For example while the modules are being prefabricated and preassembled within a factory, the foundations and the main structure can be constructed on site. These savings however are not possible when using traditional construction as the tasks have to be carried out in succession.

Summary of the Benefits thus include shorter time on site, predictable completion dates because it is not weather dependant and easier to meet restricted access time to site such as in the case of school holidays or airport closures. Using OSP in a project allows the time spent working on a site to be reduced. The implication of this is that the impact of the site on the local environment is usually for a shorter period. Site work has been known traditionally to be exposed to disruption from extremes of weather by which the use of OSP allows less time for risk, delay, and requirements for protection that will also be reduced for the particular project.

Where OSP is be used on a project, it is very important to include it in the process as early as possible, ideally at the concept design stage (Reid 1999). Lack of compatibility and increase in costs has been observed to be the most regular disadvantages where OSP are not considered at the earlier stage. OSP requires that all involved in the process go through a learning curve to optimize the benefits of using the system. Changing the design of an ongoing project that uses OSP introduces a range of problems for realignment as components are generally delivered to site to fit a specific set of dimensions. However, working to greater precision with good supervision has been observed to reduce the amount of adjustment and realignment where necessary.

Cost

Cost can be defined as all of the costs incurred for the work required by the plans and specifications for a specific project. These include labour, material, equipment, and services (Baba, 2009). However, OSP has been verified to be more expensive than traditional type of construction .The costs are usually between 10% and 30% more when using the offsite production (Neale et al., 1993). Example can be cited in the case of Prison buildings, which are constructed using modular construction method. It usually cost three times as much as those that were constructed using the traditional methods (Gates, 2005). A modular cell usually cost around £5,600 per prisoner per year to construct whereas a conventional steel framed cell will only cost £1,700 (Gates, 2005).

Other examples include the two modular residential housing developments in London and Leeds respectively, by which the earlier rental stream for each project equated roughly to the price of an additional flat (Bagenholm et al., 2001). The preliminary costs related to setting up of site in construction projects are usually reduced along with the total project duration, which eventually leads to further savings for construction projects. This is achievable because the level of site-based human resources will also be reduced considerably when using OSP as less people will be on site for lesser time.

Consequently, the need for welfare facilities, such as canteens, toilets, changing facilities, drying rooms and site offices are reduced, as well as the associated electricity, water and maintenance costs. This is because, many of these elements are now being expressed as costs per week, through reduction of the onsite program (Gibb, 1999). This enable contractors and clients the opportunity to lower the overall hires costs for the project significantly. Further cost savings are also attainable for projects that use OSP through the reduction in labour and expense costs, since majority of the construction work will be carried out within the factory at a set location.

The off site process also provide continuing employment for well trained operatives working close to their homes compared to when the construction project is through conventional construction methods. However, the work is dependent on the site location by which the workers have to either travel great distances everyday to and from the site, or work away from home and stay in temporary accommodation during the week. The costs usually filter through the contractors to the clients, either through direct expenses or through increased labour rates. Either way costs usually accumulate at a dramatic rate causing the overall cost of the project to increase. However, these cost saving are very rarely considered when deciding whether to use the offsite fabrication technique (Gibb, 1999).

The most important issue in regards to cost of OSP is the transportation of the modules. OSP usually require much larger capacity transport vehicles than the traditional approach (Phillipson, 2001). This usually generates greater costs, especially if the factory is in a considerable distance from the site location. On the other hand, in the traditional approach, all items of plant and materials have to be transported to site individually with each of the deliveries incurring some sort of a carriage cost, which can accumulate dramatically when they are all aggregated together. However, the actual costs are rarely known because the costs associated with traditional construction are not treated in the same way as they are with OSP. Gibb (1999) argues that, this is because the costs are often presented as an item within the bills of quantities or the cost schedules. As a result, the true transport costs are often unknown and underestimated for traditional construction.

It is also possible to provide additional savings by eradicating the need for rework and snagging, these improvements essentially help to eliminate the need for any additional work at the end of a project and all of the associated costs. Gibb (1999) produced the list of items in table 1 to be considered when evaluating the cost performance of OSP against the traditional construction method. This supports the fact that there are more saving opportunities in using OSP in comparison to the traditional system.

The benefits attributed to Off Site Production (OSP) are numerous and well documented (Gibb and Isack, 2003). Interview-based survey was conducted by Blismas, et al. (2006) to determine construction clients' views on the benefits of OSP. Their findings showed that clients' perceived the benefits of OSP as mainly time and quality based. However, it was pointed out that although OSP can offer direct cost benefits, the main benefits are from indirect cost savings and non cost value adding items.

Table 1: **Cost Items to consider when evaluating (OSP) against Traditional Construction**

Potential Additional Cost	Potential Cost Saving
Real costs of fabrication facility	Productivity cost savings from off-site fabrication
Additional costs from large capacity transportation	On-site savings due to shorter construction period
Additional costs from increased capacity of site craneage	On-site savings due to less on-site work
	On-site savings due to fewer construction workers
	Cost savings from less transportation
	Cost savings from reduction in unplanned on-site remedial works
	Changes to project cash flow

Source: Gibb (1999)

Based on this, a pure direct cost comparisons favour traditional on-site operations that are cost on a rate-based system, with overheads, access, repairs, and reworks hidden within preliminary costs (Blismas et al., 2006). This is because OSP costs are usually presented as all inclusive amounts with a premium for off-site overheads and much of the benefit and added value in OSP is indirect (Langdon and Everest, 2004). However, even if the cost issue remain unresolved, the supporters of off-site production present a broader case based on social and environmental issues (Langdon and Everest, 2004).

In summary cost has often been seen as the negative part of OSP because the initial elemental costs are usually more expensive. However, savings to be considered in comparison to the traditional system are: Cost certainty and reduced risk, reduced abortive work and defects, reduced prelims and site overheads, better quality therefore reduced maintenance etc, reduced construction time, which can result in cost benefit and minimise the overall lifecycle costs.

Quality

The Barker review (2003) posits that offsite technologies could improve the quality of construction and at the same time address skill constraints in the industry (Barker, 2003). Quality can be defined as an intrinsic or unique characteristic of a material, product or assembly or, having a high degree of excellence. The better the quality of a thing, the more care, and thought (often money) its maker will put into its making. OSP provides the industry with improvements in quality because a factory environment is more conducive to producing high quality products (Gibb, 1999). The work of Neale *et al*. (1993*)* examined the quality of work in OSP and concluded that this does not mean that all work conducted through conventional construction is substandard, it is just that, it has better controls and higher levels of quality can be enforced within the factories. He highlighted how climate can be regulated throughout the year when working with OSP so that operatives are not exposed to the extremes of temperature especially during the winter and summer months.

Building in factories generally offers the advantage to the workers in form of improved lighting for working condition compared to conventional construction. In conventional method of construction, the onsite staffs often have to work using temporary lighting. Consequently, the result is often substandard and as well as not being conducive to production of high quality work. This can impair the site workers accuracy and precision especially when working on complex and detailed tasks.

On the other hand, as well as working under improved working conditions, OSP also enables a more efficient sequencing of tasks for trade operatives. It works in such a way that each trade can have their own-programmed allotment in which they will have sole allocation of each module to allow them complete their work. These are usually sequenced in the order in which the activities need to be conducted.

For example, the painters and decorators will have possession of the module before the carpet fitters or tillers. It helps to reduce the risk of damage being caused by other trades when working out of sequence, which is very common in the traditional construction. In turn this will help to improve the quality of the final product and will significantly, if not totally eradicate the need for rework and snagging which is often required at the end of traditional projects (Neale et al., 1993).

OSP has the advantage of providing the opportunity to improve the methods of construction for each individual task. For example, bathroom floors can be completed on accurate moulds, which are built to suit the workforce, that is, the tradesman can work at waist level for working position and easily access all areas of the module. This allows the tradesperson to work in a comfortable position thereby eliminating the requirement to work on their hands and knees around a sink basin, which is often the requirement on site for the traditional construction method. The increased spaces within the factories also enable the labourer to walk around the mould enabling them access to all parts of the task thereby eradicating any problematic areas about vision and accessibility. This will inevitably help in providing improvements in the quality of the workmanship, and reduce the number of snags. Neale *et a*l (1993) further explained in his work how OSP offers the opportunity in introducing specialist tools and techniques in order to improve the quality of the modules.

However, the quality of the finished product could be at risk of damage during transportation and installation phase (Gibb, 1999). If this was to happen, it could have serious implications on the progress of the project, and ultimately affect quality of the finished product. Nevertheless, it is easier to manage a clearly understood risk such as damage during transportation, than trying to manage a lesser more elusive risk such as the damage to on site works by the various trades.

As a summary, OSP will not magically transform poor design, but if designed and executed correctly it will consistently achieve predetermined quality in a factory-controlled environment, reduce damage from handling and storage onsite, and limit risk of damage from follow-on trades by using sealed volumetric and modular units.

Sustainability and Offsite Production

Sustainability

There have been many definitions for '*sustainability'* and many questions about if it is even the right word to describe how we want it to be in the world. The standard and common definition however, was the one provided by Brundtland Commission Report (1987), which stated that '*sustainability*' is any development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland, 1987). The present inhabitants of the world have a duty to pass it on to the next generation in a state which is no worse than it is now (Brundtland, 1987) .'*Sustainability'*, have various dimensions, among which is the use of energy and its effect, resources and materials, water and its disposal, pollution, waste, health, well-being, and the effects of human actions on the biosphere and habitats (Banfill and Peacock, 2007). Quite simply, it is easier to reduce the environmental impact of work in a factory than it is on a construction site. OSP offers the following advantages in terms of sustainability measures:

- Less waste
- Less packaging
- Reduced environmental impact during the construction process
- Less impact on surrounding area

For the purpose of this paper, the issue of sustainability in construction using OSP will be discussed under three sections which are :environmental, economical and social aspects.

Environmental Aspects

Environmental performance is the damage caused by the interaction of the building with its environment, such as sun, wind, rain, heat, cold and water infiltration (Burden, 2005). The environment has been receiving increasing consideration especially in recent years when planning and managing construction projects (Banfill and Peacock, 2007). This is not just during the construction period, but also throughout the whole life cycle of the project. This is because people are becoming increasingly concerned with the current state of the environment and associated issues, such as the greenhouse effect and climate change with one of the biggest concerns being the effect that the construction industry has on the wider environment in terms of carbon emission.

Too many buildings are environmentally inefficient and do not make best use of limited resources. As a result, the energy used in constructing, occupying and operating the buildings represents around 50% of the greenhouse gas emissions within the United Kingdom (Environment Agency, 2003). In addition, between the year 2002 and 2003, the United Kingdom produced around 333 million tones of waste (DEFRA, 2006). Of this, the construction industry was responsible for nearly a third. That was over three times the amount produced by all households, and over twice as much as the industrial sector. Out of the 107 million tonnes of wastes that was accountable to the construction industry during this period, an amazing 13 million consisted of materials that had been delivered to site but never used (DTI, 2004).

The large majority of these wastes were those produced from projects that were procured through traditional construction methods. The reason for this is that the clients and contractors often do not have other projects in which they can fully utilize the leftover of materials, they are therefore required to dispose them. If they do have another live project, it may still not be cost effective to transport these materials from one site to another, hence degrading of the environment. However, OSP has helped in eliminating the level of all these waste. This is due to the fact that, the factory location is constant and there exists great reduction in the level of the total wastes in production regardless of if modules are being fabricated for projects in the north or south of the country. The effect of this is that any excess materials from one project can easily be transferred to another project that is being constructed within the factory or be potentially saved for future projects.

According to Phillipson (2001), this transfer has the advantage of incurring very little or no transportation costs which will in turn not only help in reducing the levels of waste produced by the industry but also provide significant cost savings for the different projects and the construction industry at large. In addition to this, it is also widely recognised that OSP helps towards improvement of the environmental performance in the construction process by controlling the amount of pollution and waste generated into the environment (DEFRA, 2006).

This is achievable because the general factory conditions will help in providing a controlled and regulated environment in which the levels of dust and noise can be extracted from the atmosphere (Baba, 2009). These factory conditions are also widely recognised as having the capability to increase the amount of recycling that occurs on construction projects.(DEFRA, 2006) This is again possible because the large majority of the construction work will be conducted within a factory and at a set location. As a result, it will be much easier to designate a set area for a recycling program, which can then be used for all other type of projects.

Traditional projects on the other hand very rarely use the same site staff and are seldom located at the same location by which any recycling program will require significantly more management, which often deters many conventional construction firms. Phillipson (2001) reported that a scheme was being developed using OSP and that it had the potential of producing 50% reduction for water used during the construction of a typical house. In addition, 50% reduction in the quarried materials usage on site can be achieved, as well as a 50% reduction in energy consumption (EC Funded Sustainable Construction Project, 1999). If this is possible then it is fair to say that the effect the construction industry has on the environment will be massively reduced, especially if other projects can achieve similar standards.

The Movement for Innovation (European Sustainability Group Report, 2001) had a working group under Rab Bennetts to look at the performance indicators required for measuring the sustainability of construction projects. They identified six (6) factors which are:

1. Operational Energy Use
2. Embodied Energy
3. Transport Energy
4. Waste
5. Water

6. Species Index per Hectare

Out of the 6 factors, the only indicator that is perceived to produce a potential negative effect on the environment is the transportation process. In the case of OSP, this is very possible because the vehicles used to transport the modules to site will need to be of higher capacity vehicles. As a result, they will inevitably produce carbon emissions and require more fuel. However, it is an accepted fact within the general literature in construction industry that transportation system OSP is still more environmentally friendly than it is with traditional construction (European Sustainability Group Report, 2001).

Economic Aspects

The EC funded a Sustainable Construction project called Future home (EC Funded Sustainable Construction Project, 1999). It sought to help EU States meet the social need of affordable housing. The project aim was to build up a pool of data on building prefabrication from low to medium rise housing, and was of the hope that it will provide the basis for developing sustainable and adaptable building concepts using prefabricated technology. The objectives of the project were to deliver: 30% reduction in construction costs; 35% reduction in construction time and 60% reduction on defects on completion (BRE, 2003) .

Social Aspects

The challenge for OSP within the housing sector is to leave behind the association of some types of system with poor quality housing and even social exclusion in some extreme cases.(BRE, 2003). Although the case is quite different for non-domestic buildings, some retail developments, fast food restaurants, and hotels have since been procuring buildings through using OSP. So far there have been little, if any, social problem that has been associated with these procurement (BRE, 2003).

Health and safety: By moving the work offsite, hazards is being removed or reduced by:

- Fewer personnel onsite reduces health and safety risk
- Offsite reduces work at height risk
- Health and safety is easier to control in a factory setting
- Manufacturing sector is six times safer than construction

Site issues: These usually play a part in all construction projects: Using offsite means less work on site and consequently less noise, dust, pollution and disruption**.**

- Offsite minimises site operations on projects within or adjacent to operational facilities such as existing hospitals, rail facilities etc.
- Offsite needs less site storage space

Offsite requires fewer deliveries

Discussion

Off-site production is currently used only to some degree in the construction industry. However, the barriers that can affect the extent of future application and development will be discussed in another paper. The most important challenge for the future of off-site production according to BRE (2003) is in how these barriers can be overcome in order not to repeat the mistakes of the past. Failure to do this can then result in off-site production not meeting potential.

Off-site production is much more than a trendy concept, it offers the possibility of remoulding construction as a manufacturing industry. It also represents one of the positive ways forward for underpinning the major changes that have been identified as necessary for improving construction(BRE, 2003). OSP has the capacity to drive down costs and improve productivity. However, the claims for the level of improvement that could be achieved must be scrutinized and evidence is required to support them. With regard to the other benefits, all the issues need to be understood and properly demonstrated before the more conservative parts of the industry can respond. This, in turn, should lead to a greater uptake of the systems as already envisaged.

The potential environmental benefits of off-site production are numerous with real assessments required for the different applications in order to show whether these benefits are marginal, or more significant, when compared to traditional methods (BRE, 2003). Furthermore, environmental legislative pressures on construction activity are likely to continue to grow in the future. If the environmental benefits can be demonstrated for some of these techniques, then they should flourish in the future.

The BRE report noted that off-site production could allow greater client choice and involvement, particularly in housing, where a variety of different systems can be realized from manufacturers. However, their application, drivers, pragmatism and perception need to be considered in the light of current technology and management practice (Gibbs, 2001). The future application of OSP should be determined by the economic and environmental benefits for the particular project. In order to ensure that these are successful, the performance of the systems needs to be established over the whole life of the structure. However, without the market acceptance of the end-product, OSP tends not to flourish. It is therefore very important to ensure that the aesthetics of the particular system also meet market demand.

Conclusions

The paper has shown that OSP has the advantage of providing the construction industry with significant improvements especially in its environmental performance within the three popular categorized sections (environmental, economical and social aspects) of sustainability. OSP reduces the waste and harmful emissions exposed to the environment whilst increasing the levels of recycling.

However, the extant review of literature in this paper has also showed how OSP requires additional coordination and commitment to tolerance early in the project than traditional or on-site built construction. Moreover, if not assembled under good weather condition or desirable project condition, OSP can result in inefficiency due to design rework and space organisation. Despite this, it is of value to know that the benefits of utilising OSP for construction projects still outweigh that of traditional construction methods.

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