Factors and Drivers Effecting the Decision of Using Off-Site Manufacturing (OSM) Systems in House Building Industry

Hussein Elnaas[1], Philip Ashton[2] and Kassim Gidado[3]

Abstract

Much has been written on Off-site Manufacturing (OSM) in construction, particularly regarding the perceived benefits and barriers to implementation. However, there seems to be a wide misunderstanding of the state of OSM associated with the concept of decision by many of those involved in decision making process within the industry. This has led to a demand for guidance's on decision making process for construction project leaders at early project stages. Choosing a construction method for a project will require an optimum decision strategy which involves careful understanding, measurement and evaluation of a number of decision factors that can have the most influence on successful decision action. This paper, therefore, aims to identify the key decision factors to be considered at evaluation stage when choosing to use Off-Site Manufacturing (OSM) as a construction strategy particularly in house building projects. This will reveal the key drivers for change in the industry forwards the use of OSM in house building.

Keywords: Decision Making, Decision Strategy, Off-Site Manufacturing (OSM).

Introduction

The UK construction industry faces increasing demands from various stakeholders and it is being expected to reduce CO2 emission and the environmental impacts of buildings; reduce overall project duration and costs; reduce defects; eliminate accidents; and improve house building supply rate and performance all within a relatively short period (NHBC House, 2009; Ross et al., 2006 and Housing Forum, 2004). Government departments and a competitive market have driven the construction industry to review its operations and seek ways of improving its management processes and delivery of new housing (Pan et al., 2007). In an effort to tackle these challenges, house builders seek alternative ways to improve their performance. It is suggested that traditional forms of construction will fail to meet future demands.

Blismas and Wakefild (2007) stated that OSM can contribute to addressing some of the challenges facing the construction industry. The potential for OSM to reduce cost, time,

1 School of Environment and Technology, University of Brighton, Brighton, BN2 4GJ, UK, Tel: +441273642284, Fax: +44-1273-642285, Email: E.Elnaas@brighton.ac.uk.

2 School of Environment and Technology, University of Brighton, Brighton, BN2 4GJ, UK, Tel: +441273642388, Fax: +44-1273-642285, Email: P.Ashton@brighton.ac.uk.

3 School of Environment and Technology, University of Brighton, Brighton, BN2 4GJ, UK, Tel: +441273642349, Fax: +44-1273-642285, Email: k.i.gidado@brighton.ac.uk.

defects, health and safety risks and environmental impact has been well established (Parry et al., 2003; Venables et al., 2004; Gibb and Pendlebury, 2005). It is further seen as a key vehicle for driving efficiency improvements within the house building sector (Housing Corporation, 2007; Homing Forum, 2002). However, Goulding et al., (2012) stated that the uptake of OSM is much lower than expected in the UK construction industry. For the uptake to improve, further literature search has identified the many issues and questions that need to addressed regarding the decision making process especially at the early stages of construction. This research suggests that these challenges can be met through investments in offsite technologies, but the decision-making to use OSM also needs to be better understood and improved.

The Concept of Decision for Using OSM In House Building

Decision making is an on-going task, carried out throughout the construction project's life cycle. It is a problem solving activity, through making a conscious choice or selecting to achieve an objective or desirable outcome.

The existing literature reveals a wide range of driving forces in the construction industry for utilising offsite technologies in different sectors such as housing, commercial or services buildings. Some research projects have exposed the drivers within the project context, for example the Construction Excellence (2006), which identified five drivers for change to use offsite technologies in the UK's house building industry namely: costumer focus, quality driven agenda, committed leadership, integration of processes and teams around the product and commitment to people.

According to Jaillon and Poon (2009), OSM has the potential to address many issues such as: the environmental challenges in terms of energy efficiency and waste reduction; improve financial efficiency through economics of scale through mass customisation (Nehmens and Mullens, 2009); and improve the social aspects of people's lives (safer, training and better working conditions) by providing job opportunity in factory environment (Burgen and Surgen, 2006). Pan et al., (2005) argued that the most significant drivers for adopting offsite technologies are addressing skills shortages, delivering within agreed time and costs and achieving high quality. In another research, Rose, et al. (2006) identified five drivers for change in the house building context. These were shortage in housing supply, skills shortage, concerns about quality, changes to Building Regulations and environmental performance.

According to Lucey, (1997), all decisions must decide by some means to choose the outcome or outcomes which are desirable to decision maker(s) and they do so after some form of appraisal of the situation. However, because of the unique nature of the construction industry, construction decisions may be more difficult because typically involve:

- Uncertainty ~ many facts may not be known
- Complexity ~ interrelated factors
- Risk-consequences ~ the significant of decision
- The vast array alternative solutions ~ these are the possibilities one has to choose from, each has its own set of uncertainties and consequences
- Interpersonal issues ~ predictability of people's reaction.

Armstrong at al., (1999) suggests that decision makers face a range of possible constraints that may include a lack of alternatives, no clear criteria, time and cost constraints; imperfections of the decision makers' perceptions; or incompatibility between attitudes. Furthermore, Pan et al., (2008) stated that significant challenges faced by decision makers

may also include increasing alternatives to choose from, more uncertainties about future requirements and the need to make quick decision.

Decision making should be based on a number of key factors and drivers in order to choose the optimum construction strategy. Choo (2006) stated that an alternative is considered optimal if it is greater than all other alternatives when a single and consistent set of criteria is used to compare all the available alternatives.

Industry professionals have expressed their interest in the process of Off-Site Manufacturing (OSM) systems in construction, however, due to the lake of expertise in the area of OSM decision making, some professionals have avoided the use these technologies (Ogden, 2010). Pasquire and Gibb, (2002) established that the major reason why contractors are unwilling to adopt OSM is because they have difficulty ascertaining the benefits that would add to their project.

The decision making process used to evaluate the application of OSM in the construction process is poorly understood according to CIRIA, (2000). Pasquire et al (2004) stated that the decision making process as inadequate with the industry, while Blismas et al (2006) said that decisions regarding the use of OSM are unclear and complex. According to Pasquire and Gibb, (2002), decisions seem to be based on anecdotal evidence rather than rigorous data, as no formal measurement procedures or strategies are available.

With increasing pressure on construction professionals to improve efficiency and to make decisions quickly, there is a lack of rational, robust and balanced decision criteria for building system selection in house building (Pan et al., 2008). There has been very little evidence to suggest that the existing decision making systems designed in the context of OSM meet the current needs of the construction practitioners. Therefore, there is a need for a selection criteria framework or mechanism to be designed based on knowledge of decision making methodology in the house building industry.

Methodology

The literature review has provided documentary evidence to the determination of using OSM as a strategy for house building projects. Employing a mixture of both qualitative and quantitative approaches for data gathering involve both semi-structured interviewing and case studying approaches. This research has focused on a typical domestic house development, thereby ensuring the unity of comparison and data analysis. These housing developments were consisted from one to four bedrooms homes, flats, apartments or accommodations units.

Interview questions were developed from issues highlighted throughout the literature review in particular the need to improve decision making and analysis with OSM choices. The primary objective of the data gathering was to canvass construction practitioners' opinions and views based on their experience of decision making to use OSM systems in the construction with particular reference to housing.

Using a criterion for selection, 30 face-to-face and phone interviews were carried-out with senior managers, clients, project managers, contractors and designers who had direct responsibility for decision making within their organisations. These include members and stakeholders of Buildoffsite – a leading member of the UK offsite construction industry.

Following the literature review and interviews, 15 case studies were identified having established criteria including: type of housing projects; based in the UK house building industry; different locations and logistics issues; completed or under construction projects; based on a volumetric, none-volumetric to modular building systems/methods of construction.

The case study approach focused on the identification of the impact of each factor identified by literature review and interviews conducted. Each case study shared facts that had been considered during the decision making process to use OSM systems. The outcomes of which were used to establish a selection criteria to assist in making decision to use OSM systems as a construction strategy.

Factors Influencing the Adoption of OSM in Housing

The interviews and case studies identified key factors that have the potential to influence decision when choosing OSM as a construction strategy. The findings reveal an overall opinion of house builders and provide the established driving forces behind the industry needing to use offsite manufacturing for the construction of housing.

The research has identified a list of about 100 factors that have influence on decision making process when considering OSM. The factors were then categorised into 16 themes to ease the management and comprehension as shown in table1.

Table 1: key factors for using OSM in housing

	Factors	Responses		Importance Ip (%)	Influence/ Impact
		No.	Frq. (%)		
1	Time	45	100	97	Highly Important
2	Quality	39	87	76	
3	Cost	36	80	60	
4	Predictability	26	58	42	Moderately Important
5	Productivity	22	49	35	
6	Interface issues	21	47	29	
7	Environment issues	20	44	26	
8	Performance	19	42	26	
9	Labour	16	36	23	
10	Lack of space	15	33	21	
11	Safety	13	29	14	Neutral/usually Important
12	Project Complexity	10	22	12	
13	Logistics Issues	10	22	10	
14	Availability of resources	8	18	8	Not Important
15	Planning Issues	6	13	5	
16	Market Condition	5	11	4	

The research has established the 10 most important factors that can influence on decision when considering OSM as construction strategy based on the importance index (Ip): $Ip = 100 \sum (af)/AF$.

Drivers for Change to Use OSM in House Building Industry

Whilst the literature review identified generic drivers for change, it is essential that the decision for using OSM is viewed from a project-wide perspective in order to develop a suitable strategy.

Using 30 interviews, the research has reviewed the drivers for adopting OSM with specific reference to house building. It identified 12 key drivers for change in the construction culture to use OSM in house building projects. These key drivers have been categorised into 5 categories, namely: organisational, technical, economic, environmental and social. The results are shown in table 2.

Table 2: Drivers for Using OSM in house building

Categories	Drivers	Percentages	
		%	Avg. %
Organizational	Revisions to Building Regulations to support OSM	67	60.67
	Government and Industry's agenda and concerns	73	
	Committed leadership in the entire industry	42	
Technical	Shortage in housing supply	90	89.67
	Projected skills shortage	86	
	Concerning quality of new housing	93	
Economic	Reduction in overall project cost	69	72.50
	Integration of project processes	76	
Environmental	Environmental performance of buildings	86	66.50
	Reduction in accidents and ill health of project environment	46	
Social	Employment opportunities away from building sites	46	53.00
	Product and end-user focus	59	

The interviews also identified the key constraints that prevent take-up of using the system in the housing sector, as follows:

- Early design freeze ~ late changes not easy to accommodate
- No legal framework available to support OSM
- Lack of understanding of OSM by local authorities
- Mortgage to OSM due Lack of codes and standards to OSM
- Regulations are too old – to cover all offsite aspects
- Limited the UK capacity in OSM to enhance its use and efficiency
- Possible increased consequences of incidents on site

These current constraints of using OSM are very similar to those identified from the existing literature and are reflective of the industry's traditional fragmentation.

Discussion

The research has confirmed that time, quality and cost are the main key factors which have the highest impact on the decision for using OSM in house building. They score an importance index of 97%, 76% and 60% respectively.

There is an overall saving in programme time; this reduction is obtained through the overlapping of offsite and onsite activities which would be done in sequence using traditional methods. Thus, the reduction in project time should lead to reduction in the overall cost of project. However, due to the reduced on-site time, there should also be a reduction in the preliminary costs associated with the major contractor's site setup costs.

Achieving the highest quality was highlighted as one of the main key factors may be because quality control and assurance procedures are easier to apply in the factory environment. Working under factory conditions also gives better control, productivity and quality of end product; where offsite works are completed in advance of the onsite installation, the products can be tested and proved before they are transported and incorporated into the building.

The predictability, productivity, interface issues, environmental issues, performance, labour, safety and lack of space, are considered as moderately important. Predictability of building performance factor was stayed on the top of moderately important factors may be because clients' need to be able to control their risks and uncertainty by reducing or eliminating unknowns; followed by productivity factor of their impact on decision, their importance standing at 42% and 35%, respectively. Safety, project complexity and logistics issues factors were identified as neutral/usually importance influence. The less affected factors in terms of the importance were availability of resources, planning and market condition.

From this study, most important drivers for change in the industry to use OSM in house building were identified and grouped into five categories of drivers: technical, economic, environmental, organizational and social. The rating percentages of responses are 89%, 73%, 67%, 61% and 53%, respectively. Each category is made up of a number of drivers as shown in Table 2. The most highly rated category was technical drivers. House builders believe that the use of OSM systems can improve the rate of house building for many of its advantages to deliver the demand/target and quality of new housing. They also indicated that industry's skill shortage can be addressed by use of the system because most of work will tack place in factory environment. Although, OSM in itself may not reduce the amount of labour; instead it changes the location of work and the workforce from site to factory, or to use the available labour more effectively.

Among economic drivers, reduction of overall project cost and integration project processes were regarded as high priority in this category. Integration of design, manufacture and construction processes can contribute to the achievement of schedule and planning goals and many in higher field efficiency and cost efficiency on long term of project/facility.

Figure 1 graphically maps out the relationship between the factors and drivers in the context of decision making process when considering using OSM as construction strategy for house building. All of these need to be considered at evaluation stage for decision to use the system that can have the greater potential to affect project outcomes.

The figure also illustrates that the decision for using OSM in house building is driven by defining the project drivers based on number of key factor that can have significant influence on decision making, and then considering the benefits of various options (offsite *vs.* onsite) against those drives.

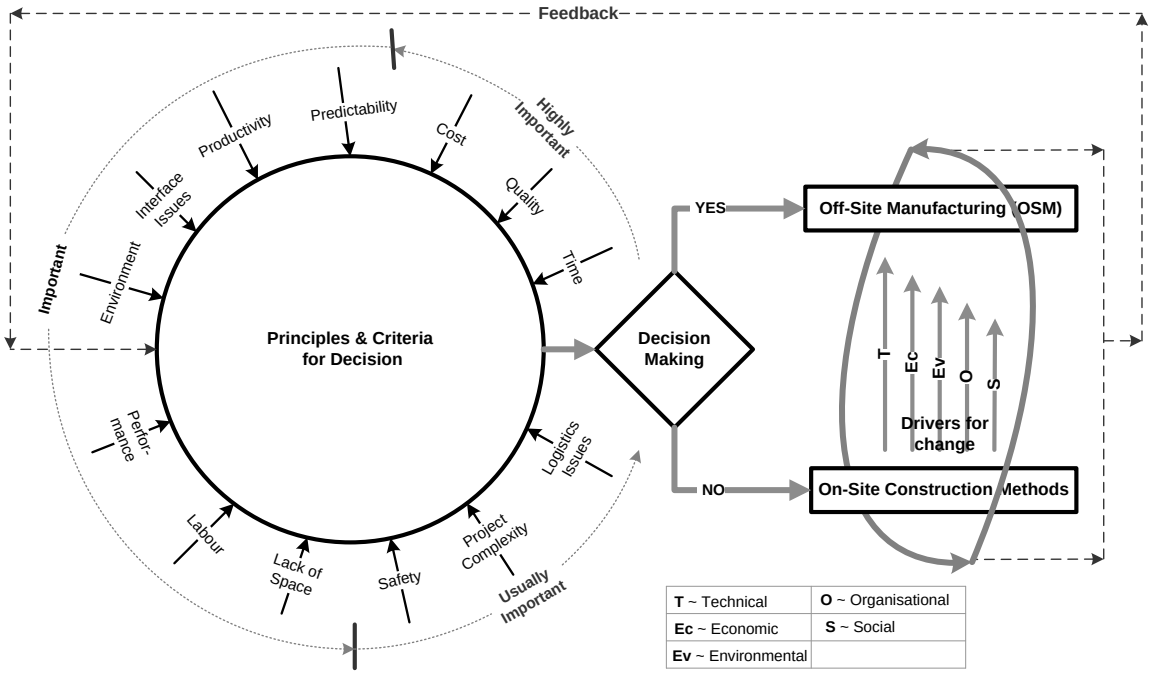

Figure1: Relationship between decision factors and drivers for adoption OSM

Conclusion

House building industry has the potential to address some of the challenges that are facing the UK construction industry in particular to:

- Reduce CO_2 emission and environmental impacts
- Reduce overall project duration
- Improve housing supply
- Reduce defects in new housing
- Reduce accidents and ill health on construction sites
- Reduce overall project costs and improve building performance.

There are concerns that traditional construction methods cannot deliver these demands. This research concur with others that suggest OSM could contribute to achieving the government and industry targets; but in order to achieve these improvements, decision making to choose onsite or offsite needs to be better understood.

Making a decision is an important part of all construction industry sectors, where specialists apply their knowledge that fit a set of indicators; relying upon analysis of massive amounts of information/data, facts and belief. Decision making criteria used to evaluate OSM in house building if better understood would become more accepted by end users, builders, regulators, lenders and other government and client bodies. This paper has

revealed key factors and drivers to be considered at the evaluation stage when deciding whether or not to use OSM as a construction strategy for house building projects.

The research has established that the application of OSM systems in housing can be part of a strategy to speed up construction, improve quality of end facility, predictability of performance and increase overall productivity, reduce labour on-site with its attendant costs and health and safety, and minimise environmental impacts. The research also identified 16 key decision factors that need to be addressed when considering OSM during the evaluation stage for a project. Again, the research has identified the key drivers for the house building industry to adopt OSM systems. Whilst the key factors frequently have most influence in decision making, it is the drivers that have the greater potential to affect decision outcomes.

The paper has developed a conceptual model describing the relationships between the identified key factors and drivers for change forwards the use of OSM in house building industry. The model clearly indicates the significance of feedback and continues improvement of the quality of the decision making.

The move to OSM also essentially requires an entire integration and coordination of design, manufacturing and construction processes, in order to improve quality and delivery of new homes. This can be a recommendation for further research.

References

Armstrong, J., Dixon, R. and Robinson, S. (1999) The Decision Makers: Ethics for Engineers. Thomas Telford Publishing, London.

Blismas, N.G. and Gibb, A.G.F., (2002) Considerations for Assessing the Benefits of Standardisation and Pre-Assembly in Construction. Journal of Financial and Management of Property and Construction, Vol. 7, Number 3, December 2002, pp. 151-161, ISSN: 1366-4387.

Blismas, N.G. and Wakefield (2007) Drivers, Constraints and the Future of OffSite Manufacture in Australia. Produced by CRC for Construction Innovation Special Edition 2008. QUT, 27575.

Blismas, N.G., Gibb, A.G.F. & Pasquire, C.L., (2006) Benefit evaluation for offsite production in construction, Construction Management and Economics, 24 (2), February 2006, pp. 121-130, ISSN 0144 6193.

Burgan, B.A. and Sansom M.R. (2006) Sustainable steel Construction, Journal of Constructional Steel Research. 62(11), 1178-1183.

Choo, C. (2006) The Knowing Organization: How organizations use information to construct meaning, create knowledge, and make decisions, 2nd ed. Oxford University Press, Oxford.

CIRIA, and principal author Gibb, A. (2000) Client's Guide and Tool Kit for Standardisation and pre-assembly, Construction Industry Research and Information Association (CIRIA), 2000, Report CP/75, 70 pp. ISBN 0860 175448.

Construction Excellence (2006) Movement for Innovation (M4I), London.

Homing Forum (2002) Homing in on Excellence: A commentary on the use of offsite fabrication methods for the UK house-building industry. London: The Housing Forum.

Housing Corporation (2007) Modern Talking: Building better value homes using modern approaches. February 2007, London.

Housing Forum (2004) Manufacturing Excellence: UK capacity in off-site manufacturing. London: The Housing Forum.

Gibb, A. and Pendlebury M. (2005) Glossary of Terms. Buildoffsite: Promting Construction offsite, London.

Goulding, J., Rahimian, F., Arif, M. and Sharp, M. (2012) Offsite Construction: Strategic Priorities for Shaping the Future Research Agenda. Architectoni.ca 2012, 1, 62-73.

Jaillon, L. And Poon, S., (2009) The Evolution of Prefabricated Residential Building Systems in Hong Kong: A review of the public and the private sector. Automation in Construction, 18, 239-248.

Lucey Terrt (1997) Management Information Systems, 8th ed. DP Publications, London.

Nahmens, I. and Mullens, M. (2009) The Impact of Product Choice on Lean Homebuilding. Construction Innovation: Information, Process, Management, 9(1), 84-100.

NHBC House (2009) Deffining A Fabric Energy Efficiency Standard for Zero Carbon Homes: Executive Summary of Task Group Recommendations, November 2009, London. www.zerocarbonhub.org .

Ogden, R. (2010) Year Book: the Buildoffsite vision. July, 2010, Buildoffsite, London.

Pan, W., Gibb, A. and Dainty, D. (2005) Off-site Methods of Construction in Housing: Perspectives and Practices of leading UK House-builders. Published by Buildoffsite. Loughborough University, Loughborough, UK.

Pan, W., Gibb, A. G. F. and Dainty, A. R. J., (2007) Perspectives of UK House-builders on the use of Off-Site Modern Methods of Construction, Construction Management & Economics, Vol 25, No 2, 2007, pp. 183-194, ISSN 0144-6193.

Pan, W., Gibb, A. G. F. and Dainty, A. R. J., (2008) Leading UK housebuilder's Utilisation of offsite modern methods of construction, Building Research and Information, 36(1), 56-67.

Parry, T., Howlett, C. and Samuelsson-Brown, G. (2003) Off Site Fabrication: UK Attitudes and Potentials – BSRIA, Report 17356/1.

Pasquire, C. and Gibb, A. (2002) Considerations for Assessing the Benefits of Standardisation and Pre-assembly. Journal of Financial Management of Property and Construction, 7(3), 151-61.

Pasquire, C., Gibb, A. and Blismas, N. (2004) Off-Site Production: Evaluating the Drivers and Constraints Proceedings of the 12th Annual Conference on Lean Construction, Copenhagen, Denmark, 3-4 August.

Ross, K., Cartwright, p. and Novakovic, O. (2006) A Guide to Modern Methods of Construction. The BRE Housing Innovation Centre Published by IHS BRE Press on behalf of NHBC Foundation.

Venables, et al. (2004) Modern methods of construction in Germany: playing the off-site rule. Report – Pera Innovation on behalf of the Department of Trade and Industry, UK.