DECISION MAKING PROCESS FOR USING OFF-SITE MANUFACTURING SYSTEMS FOR HOUSING PROJECTS

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Initial research seems to suggest that the use of Off-Site Manufacturing (OSM) approach for housing projects in the UK could improve efficiency in terms of functionality, quality, time, safety and sustainability. There is a verity of OSM systems from volumetric to non-volumetric, which form substantial parts of the building transported to site and installed quickly with a minimum of on-site works. The decision to use OSM systems in housing projects is an important and challenging feature of modern building construction technology. The challenge mainly results from the variability of OSM systems and lack of sufficient information and inadequate decision support systems available to assist decision makers select the most appropriate construction system. This paper investigates the nature and composition of the decision making processes used to decide on the choice and use of OSM approach in buildings and offers a flowcharted developed to support the client's decision making process to use or not to use OSM in the UK building industry.

Keywords: site manufacturing, prefabrication, modular construction, decision making.

INTRODUCTION

Off-site Manufacturing (OSM) has been employed in various ways in the UK since 1950. Its early use was mainly for temporary buildings such as army accommodations and stores (Venable, *et al.*, 2004, p: 6). According to CIRIA, there exists three key assumptions underlying the use of OSM systems in housing; firstly after the Second World War, founded on ideas from the manufacturing industry economics of scale in the production increase by using of OSM components. Secondly, standardisation for many of its benefits that can aid to overall project outcomes and finally, the need for continuity of workload to ensure a steady use of the factory assembly line lend themselves to OSM (SP. 139, 1996).

In the UK, the construction industry produces contributes to approximately 6 and 10% of the National GDP. The value of construction output for example in 2000 was approximately £58 billion with repair and maintenance of existing infrastructure and facilities accounting for nearly 50% of the total (DTI, 2006). New homes, according to the National Housing Building Council about 10% of are built using timber frames, and 5% using other MMC forms, equivalent to approximately 25,000 homes per year (POSTnote, no. 209, 2003).

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According to Barker Review, the government is encouraging MMC that can achieve "a step change in construction industry to produce the quantity and quality of housing we need" (2003). The Department of Trade and Industry, the government's most recent initiatives committed to do so with the acceleration in the adoption of off-site technology and required support from all the industry' stakeholders (DTI, 2006). This raised the level of interest in off-site techniques for its potential.

The Department for Environment Food and Rural Affairs also suggests that off-site construction can deliver measurable improvements in quality, cost reduction and time predictability, and minimise safety risks on-site in both the private and public sector, among with fundamental assumptions such as client and end user satisfaction (DEFRE, 2007). This research suggests that OSM systems provide an opportunity to embrace a range of technology and processes of off-site production and on-site assembly and could contribute towards achieving these government objectives.

According to Venables *et al.*, 2004, "there is widespread concern that the rate of construction of new housing in the UK is insufficient to meet current needs which suggested that construction of between 350,000 and 400,000 new homes annually is required". While the reasons for this shortfall may be the subject of debate, this research suggests that traditional construction methods using traditional techniques based on the labour and plant on site will struggle to meet current targets of production and the demand set by government for new housing.

This research is aimed to develop a decision making methodology that can be used by practitioners when making a decision to use or not to use off-site manufacturing in housing projects. To achieve the aim, this research carried out literature review; an extensive combination of face-to-face and telephone interviews; and a self-administered questionnaire survey of key stakeholders in the UK's construction industry. It primarily addressed OSM systems in the house building sector with particular reference to decision making process. The study was guided by the following research objectives:

- To establish a common understanding of OSM system;
- To identify the processes and key milestones that are involved in decision making for using OSM systems in construction;
- To appraise existing models and develop a conceptual model of decision making for using OSM systems in housing projects.

This research suggests that the use of OSM systems could provide an opportunity to increase the production and output rate of new housing if its true implications and processes are understood and managed accordingly. There is reason to suggest that the availability of decision making tool to support and improve the understanding of OSM systems should enhance the take-up of OSM approach in construction further.

IDENTIFICATION OF OFF-SITE MANUFACTURING (OSM) APPROACH

Modern Methods of Construction (MMC) according to Ross is a collective term used to describe a number of construction methods (2006, p:3-4); adopted by other terms such as off-site construction, off-site manufacture, Modular construction, and prefabrication technology. Also according to Tatum *et al.* (1986) prefabrication was defined as "a manufacturing process, generally taking place at a specialised facility, in which various materials are joined to form a component part of the final installation".

Modern Methods of Construction (MMC) was described to encompass technical improvements in prefabrication, encompassing a range of on-site and off-site construction methods (Danby and Painting, 2006). However, the Commission for Architecture and the Built Environment defined MMC and set its relationship with OSM as "MMC is abroad category that embraces a variety of build approaches including Off-Site Manufacturing (OSM). Whereas all OSM systems may be regarded as falling within a generic MMC heading, not all MMC may be regarded as OSM" (CABE, 2009).

The National Audit Office defined MMC as a process to produce more and means for achieving better quality homes, with aim of improving business efficiency, customer satisfaction, environmental performance, sustainability and the predictability of delivery times (2005, p:3).

However, Venables *et al.*, defined OSM approach in term of labour demand as "one means of increasing production without a corresponding increase in the demand for site labour is to move to off-site manufacturing" (2004, p:3). The research found that the types of OSM used in house building, which established as non-volumetric OSM, volumetric OSM, and modular building. Though, its systems classified as volumetric, panellised, hybrid, sub-assemblies and components, and non-volumetric OSM.

There are many terms and definitions used in the context of off-site technology systems in construction, many broadly based than a particular focus on the product within construction environment. This research provides the following definition for the Off-Site Manufacturing (OSM) approach as "all those building elements and components that involve a number of manufacturing processes in factory environment, which often engages standardisation and uses of more effective materials. That can deliver all the aspects of sustainability needed for the end-product from design and manufacture activities to final installation operations on-site, to produce more, better quality in less time, providing more confidence to client and end user", and it is this definition that has been adopted throughout this research.

DRIVERS FOR USING OSM APPROACH

The UK construction industry is under continual pressure to raise productivity, reduce costs, improve quality and reduce environmental impacts (Wilson, *et al.*, 1998). The need is also to deliver what the client demands at the right time and the right construction method for a project – these needs are the drivers of change in the industry.

There are several government-backed reports (ODPM 2003; Barker 2003; Venables *et al.*, 2004) who suggested that OSM approach could be part of the solution for addressing the under-supply of housing and wide concerns over the need to improve performance, quality, environmental impacts and sustainability. During the Housing Market Intelligence conference in 2004, Housing Minister Keith Hill commented, "We see Modern Methods of Construction as a key component to stepping up performance … but our industry has been very, very slow to respond to that" (Pan *et al.*, 2005).

Ross of the Building Research Establishment suggested that "market forces are driving the industry to reconsider their approach to serving their customers. Government agendas on Rethinking Construction, planning policy and building regulations are forcing the industry to reconsider the way houses are built. These issues are together with a construction skills shortage and a huge demand for new

houses means that innovative construction types are being developed and used" (2002, p: 4).

According to the National Audit Office, the government is committed to promoting the use of Modern Methods of Construction (MMC) in home building. In particular, ODPM spend £1.1 billion a year on building affordable housing using MMC, including £ 0.5 billion using OSM systems. English Partnerships encourages MMC across all its programmes and particularly in exemplar projects such as the Millennium Communities programme, is running a competition to build homes for £60,000 or less, with many short-listed entries involving modern methods of construction (2005, p:3).

WRAP stated that the UK construction industry consumes more than 400m tonnes of materials each year, generating 100m tonnes of waste. Research carried out by WRAP has also stated that off-site construction can reduce on-site waste by up to 90% (YORKON, 2008). They suggest that this is because much of the work takes place in a controlled factory environment, which makes waste segregation and recycling much easier.

FACTORS AFFECTING THE USE OF OSM SYSTEMS IN THE UK

Literature has provided a body of support the suggestion that there are key drivers that if know and applied could enhance the uptake of OSM in construction further: revisions to Building Regulations, shortage in housing supply, skills shortage, health and safety risk reduction, and environmental performance, seem to be some of these aforementioned derivers.

This research carried out a series of interviews and questionnaires aimed to look at the significance key stakeholders views and opinions on the use of OSM in their projects and those who have been involved in decision making process from theoretical point of view of the current practice in the UK construction industry and manufacturing of OSM components. Over 150 questionnaires provided the follows factors in support of using and developing to the use of OSM systems in housing:

- 95% ~ Speed up construction and installation on-site
- 80% ~ Quality of end product
- 80% ~ Reduce interface problems on-site
- 75% ~ Reduce labour cost on-site
- 75% ~ Increase overall labour production
- 72% ~ Minimise environmental impacts
- 62% ~ Reduction overall cost
- 60% ~ Quick client return on investment
- 59% ~ Improve managing process on-site

Regard to cost also, 77.5% of the respondents ranked that 'still cheap to import' as the strongest reason when we asked 'why UK' house-builders are still import OSM units from abroad'; but they may pay more for transport of the units.

However, the survey also identified the following reasons that OSM systems are not widely used in construction particular in housing. A new decision flowchart or guide would have to address of OSM systems were to the used and increased in the UK housing industry:

- 80% ~ Culture of people (need traditional methods) and resistance to change.
- 73% ~ Cost OSM units.
- 68% ~ Unfamiliarity with OSM' systems.
- 59% ~ Availability of OSM plants.

The research established that a major constraint to decision making to use OSM is early design freeze. Though, there are number of constraints found that may have effect on decision making for using OSM systems as gathered through the survey:

- 80% ~ Client's experience,
- 77% ~ Availability of information
- 76% ~ Skills of project team
- 76% ~ Availability of time and economic comparisons

In addition, there other constraints with less effect were found such as cost implication, site location and access, and complexity of project.

The survey established that the decision making for using OSM should take place at early stages of project life-cycle to maximise the benefits according to Gibb (1999, p:228). Although, 87.5% of the respondents indicated that the decision making should occur during the feasibility study stage before the project moves to scheme and concept design; and the remaining 12.5% of the respondents pointed to briefing stage.

This research also extended to investigate stakeholders' key lessons learnt from using OSM systems such as: satisfied customers' needs; high media attention; better communication between 2nd fix trades; improved on-site operations management; cost implications if manufactured incorrectly; early design freeze – difficult to accommodate; and Building Regulations are too old – to cover off-site aspects.

CONCEPTUAL DECISION MAKING MODEL FOR USING OSM

Introduction needs to develop a decision making model that includes the current requirements, suggestions and recommendations, and improve on current understanding. An effective decision making tool needs to recognise initial stages for achieving. These are including, how the clients' set their statement of need, identify and develop client's requirements and transfer them to construction language. Also which techniques and tools will be used to evaluate the context of different parties' requirements and constraints that can aid value to a project when decision is made to use OSM in particular project.

Properly, the main key issue of developing the conceptual model to use or not to use OSM approach is the client requirements and constraints for a project. The British Standards Institution (2006) states that typically client's requirements relate to:

- The benefits sought from the project (e.g. return on investment, payback period);
- The functional requirements expected of the product; and
- The timetable for delivery of the product.

Furthermore, the Institution of Structural Engineers (1999) observed other needs for the client that to provide: Rapid, cost-effective solutions; Quality of end-product; and Satisfy end-users' needs.

Although, Gibb, 1999; and Wilson *et al.*, 1998 claimed that Client constraints typically are related to the following:

- The available budget and any constraint associated with cash flow;

- Completion on time;
- Minimising environmental effects;
- The available resources;
- Predictable project outcomes; and
- Repeat business opportunities.

The feasibility evaluation stage is as a rule aimed to confirm that the client's requirements and business case for the project can be met through applying a type of construction procedure and to establish in principle form of the product, or can not meet those desires in the initial project 'statement of need' by those available resources (budget and time). Though, when alternative construction methods and solutions are considered during this stage, is more likely to come across a method that will be the best solution for the project, with supporting evaluation evidences.

In order to provide a decision making process for evaluating the use of OSM systems, a Conceptual Decision Making Model and Management Process Model for project-based OSM systems has been developed.

FLOW CHART METHODOLOGY FOR PROJECT-BASED OSM SYSTEMS

Developing a project-wide strategy for using OSM is fundamental and should be agreed as early in the project process as possible. In order to maximise the benefits to the project outcomes at all stages throughout its life-cycle and identifies the timing for the key decisions from an overall project perspective rather than an individual element view.

The decision making flow chart has been developed in order to achieve the 3rd objective of the research. Its development is based on findings and recommendations of this research as well as key lessons learnt and guidance's through other advanced research works that are widely established and accepted such as (a guide to modern methods of construction by NHBC, 2006; Offsite modern methods of construction by Pan, *et al.*, 2005; a guide to off-site construction and procuring a modular building by YORKON 2008). Where, the proposed conceptual decision making model is considered as the main tool that can use for the evaluation process during feasibility study stage to use or not to use OSM approach in particular project, because it is addressed all the expectations that are necessary for appraisal process of the decision making.

The flow chart has expanded throughout the whole project life-cycle processes for using OSM approach that could be the best practice in order to give a fully understanding to the house-builders in the industry. As Burke (2003) pointed out the project life-cycle subdivides the scope of the work into sequential project phases. PMBOK, 2006 states; "… because projects are unique and involve a certain degree of risk, companies performing projects will generally subdivide their projects into several project phases to provide better management control".

Therefore, the flow chart methodology has been designed as shown in (Figure 1) through those project phases which are: inception /briefing, feasibility study, concept design, detailed/engineering design, manufacture and construction, and commissioning. Also, a step further considered characteristics, processes and assessments that are involved into the chart such as: a simple aim has set for each

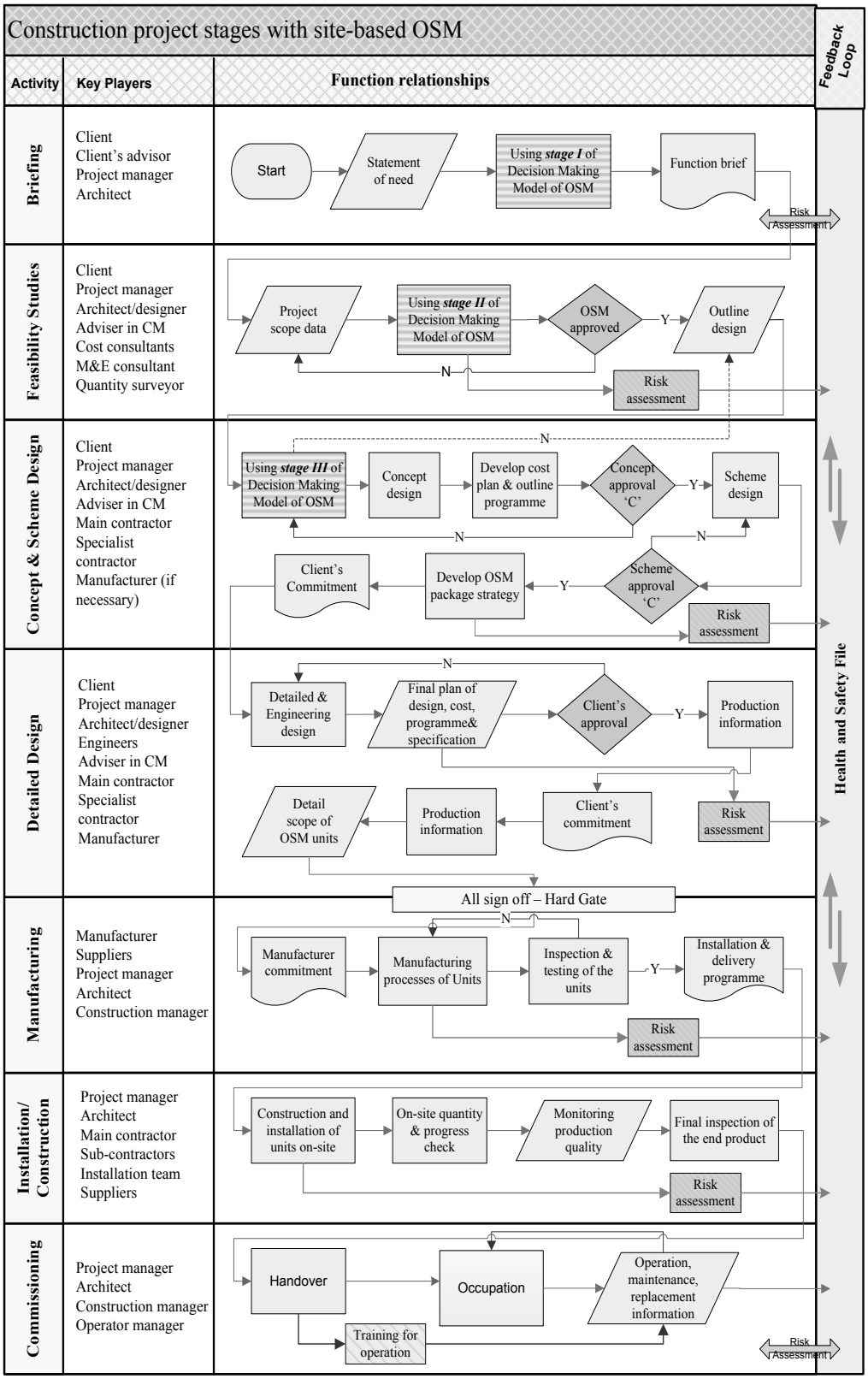

Figure I: Decision Making Flow Chart for Using OSM systems

phase, key players who involved in and have most influence in the processes of each phase, and risk assessment and H&S file are considered at every phase throughout the chart' feedback-loop.

Although, among the project life-cycle stages should contain a number of control points, which can be considered in the model. These points are logically best if located at the interfaces between phases, at which the project is critically reviewed to provide a full supervision review that should be carried out to give the rights to move to the next phase.

The flow chart is ended at commissioning and hand-over stage. But logically it does not the end with the availability of feedback-loop, because the OSM units through project life-cycle likely need to involve the manufacturer or supplier again for maintenance and replacement after the occupation, and the designer could be involved again for future changes on the property. It is also essentially that the flow chart methodology has aimed to monitor and evaluate the end product even after handed over and the occupation with feedback-loop for further work on similar projects.

CONCLUSIONS

The application of OSM systems in construction can be used as part of a strategy to speed up on-site activities and reduce labour on-site with its attendant costs, concerns with skills shortages. OSM approach itself does not reduce the amount of labour; it changes the location of work and the workforce from site to factory environment, though further research needs to be carried out this.

This research has established that the main reason for using an OSM system was: to build home more quickly and efficiently, reduce the overall construction period with rapid installation on site, provide a high quality end-product, and reduce construction waste. However, there have been disadvantages of using OSM system highlighted within the research; these have included the need to freeze early design, poor public perception of OSM and the greater initial outlay and expense of commissioning and purchasing materials for manufacture; however this does not necessarily mean OSM in a more expensive solution.

If OSM is to become more widespread, there is a need for further research to establish a total cost comparison to include all aspects of the project (e.g. whole life-cost, waste management, environmental issues and long-term sustainability), thereby highlighting the economic contribution OSM could make.

The decision to use OSM should take place at the feasibility stage not later than this in order to maximise the benefits of using the system. Advisors in construction methods and manufacturer(s) influence the effectiveness and efficiency of projects; this researches conceptual model for decision making has been developed based on this researches investigation. The proposed decision making model has been designed for and is applicable to the house-building industry.

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