ENCOURAGING THE APPROPRIATE USE OF OFF-SITE PRODUCTION (OSP): PERSPECTIVES OF DESIGNERS

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Abstract: The construction industry is being challenged to be more innovative in order to better satisfy the needs of clients and to enhance business competitiveness. Off-site production (OSP) offers significant opportunities for achieving improvements in process and productivity performance, especially in terms of delivering high quality, defect-free construction. Indeed, OSP is increasingly seen as a key part of the solution to improving the quality of construction and addressing skills constraints. However, many industry stakeholders have not realised that OSP requires systematic and strategic integration if these benefits are to be realised. In addition, many remain sceptical of the potential of OSP technology, particularly given the past failings in OSP practices. There is also an apparent lack of knowledge how to appropriately integrate different OSP techniques into the design process. After reviewing the concept of innovation, different levels of OSP techniques, and the current practices of UK architects and designers, this paper explores the drivers and barriers inherent in integrating OSP into the UK housing sector. This was examined through a range of interviews with architects and other designers. The findings reveal that barriers to the acceptance of OSP are centred around human perceptions grounded in the historical failure of off-site practices to deliver improved performance, technical difficulties (e.g. site specifics, delivery issues, interfacing problems, cost), lack of opportunities for benefiting from economies of scale, and the fragmented structure of the construction supply chain. This paper also discusses traditional and improved design processes (DFMA) in which major changes in the design role and the composition of the design team are called for. The findings of this study form part of a three-year on-going study which aims to explore the successful integration of OSP in the UK housing sector.

Keywords: Designers; Housing; Innovation; Off-site production (OSP).

Introduction

There has been an intense pressure in the UK housing market associated with a strong government and industry concern to improve the performance of the industry. ODPM (2003) sets ambitious housing and planning targets for the period 2003 - 2006. Barker (2003) claims that under supply of housing is constraining economic growth and prosperity. This report reveals that there is a shortfall in production of between 93,000 and 146,000 homes per annum. The report suggests that new technologies could both improve the quality of construction and assist with addressing skills constraints in the industry. Barlow *et al.* (2002) also argued that there was a substantial under-supply of new housing in the UK. It suggested that around 225,000 new homes will be needed each year in England alone to meet the demand arising from demographic changes and other needs up to 2016. Traditional methods are unable to meet housing demand nor to build products to a high enough standard while offsite fabricators are able to deliver good, factory-built products at the right price. Together, these factors make a powerful case for increasing the use of OSP. However, the OSP practices in housing

are lagging behind what these reports expect. The industry has been slow to innovate and adopt alternative construction technologies. While, the process of structured change must occur if the housebuilding industry is to face a sustainable future (Hooper 1998).

Much work has been done recently to identify the barriers against the uptake of OSP and offer recommendations on how to promote the related applications. However, most of them have been carried out from the perspective of manufacturers and suppliers (e.g. Housing Forum 2004), market and clients (e.g. Edge *et al.* 2002); AMA 2002) or the industry as a whole (e.g. Housing Forum 2002, Barker 2003). Very little work has been done on the designers' perspectives. Effective design in housing reaps social, economic and environmental benefits and should embrace innovation and OSP. While without appropriate integration into the design process, the benefits of OSP cannot be realised (Randall 2003).

Based on the literature review and several exploratory interviews with architects and other designers, this paper aims to explore the drivers and barriers inherent in adopting OSP techniques in the UK housing sector and discuss the strategic and systematic integration of OSP into the design process. The research questions were identified through the literature review and the topic was further narrowed down through exploratory interviews. Potential case studies have been identified to further explore the interactive relationship between the wide range of barriers and the process of strategic integration of OSP and ultimately develop appropriate strategies for the industry.

The Concepts of Innovation and OSP

There have been many definitions of innovation in the literature (e.g. Rogers 1995; Egbu and Young 1998; Van De Ven 1986; Barrett *et al.* 2001; etc). After synthesising these ideas, Pan et al. (2004) suggests that *newness, unit of adoption, and successful exploitation of new ideas* are the elements of innovation but these elements embrace rich *context* which should be understood appropriately. As Trott (2002) argues, what is new to one company may be old to another; what is viewed as a success today may be viewed as a failure in the future; and it is context-dependent how to judge success, e.g. in terms of commercial gain or scientific achievement. There is really no right answer to whether or not innovation should be successful. It should also not be assumed that the diffusion and adoption of all innovations are necessarily desirable (Rogers 1995). To better understand innovation, Pan et al. (2004) present a contextual model which includes macro-time related, micro-time related, macro-spatial and micro-spatial aspects with a wide range of contextual factors covered such as historic, spatial, political, economic, social, technological, environmental, legal. This facilitates the identification of the drivers for and barriers against innovation.

For the concept of OSP, this research takes the definition by Gibb (1999): "*a process which incorporates prefabrication and pre-assembly. The process involves the design and manufacture of units or modules, usually remote from the work site, and their installation to form the permanent works at the work site. In its fullest sense, off-site fabrication requires a project strategy that will change the orientation of the project process from construction to manufacture and installation.*" Levels of OSP are shown

in Table 1. This study focuses on levels 2-4 given that Levels 0 and 1 are already exploited within the housebuilding sector.

Table 1: Levels of OSP and definitions *(prOSPa 2004)*

Level 0	Basic materials	With no pre-installation assembly aspects
Level 1	Component sub-assembly	Small sub-assemblies that are habitually assembled prior to installation
Level 2	Non-volumetric pre-assembly	Planar, skeletal or complex units made up from several individual components – and that are sometimes still assembled on-site in 'traditional' construction
Level 3	Volumetric pre-assembly	Pre-assembled units that enclose usable space – can be 'walked into' – installed within or onto other structures – usually fully finished internally
Level 4	Modular building	Pre-manufactured buildings - volumetric units that enclose usable space but also form the structure of the building itself – usually fully finished internally, but may have external finishes added on site

However, this study also includes hybrid systems[1] and adapted modular building techniques[2] to entertain the evolution trend of OSP techniques in order to better satisfy clients' requirements and clear up the technical constraints of existing techniques.

UK Housebuilding Industry

The literature discloses a problematic context for the housebuiding sector in the UK:

Characteristics of the industry. Barker (2003) chacterises the industry as comprising: low levels of responsiveness to demand; a cautious approach to investment in brownfield development; and low levels of innovation. Ball (1999) also identifies: consumer conservatism exacerbated by the need to ensure 'saleability' for the subsequent purchasers; a high degree of instability in housing market cycles and increasing volatility in cycles; the dominance of sub-contracted labour, encouraging the maintenance of existing techniques and skills, with low training levels; the distinctive market structures between the housebulding and building materials industries, resulting in slow diffusion of innovation; and land development profits and the planning regime may discourage innovation in production and design respectively.

Structure of the industry. Almost 90% of new homes built in the UK are constructed by private housebuilders (POST 2003). There are currently around 18,000

[1] Hybrid system - A combination of volumetric pre-assembly (at the high value areas such as kitchen and bathroom and sometimes called pods) and non-volumetric pre-assembly (mainly the panellised system for the rest of structure). Details please also refer to (Housing Forum 2004: p14); (Housing Forum 2002: p21).

[2] Adapted modular building techniques – normally used for city centre residential developments. Modules are fully assembled and normally furnished in the factory and being craned into place on the steel frame structure, which solves the height structural constraints facing normal modular buildings.

housebuilders registered by NHBC, but just under 200 firms produce more than 50 homes per year in the UK.

Current challenges facing the industry. The housebuilding industry is frequently criticized, not only has the volume of output not responded to meet demand but the nature of housing being produced does not meet the needs of consumers and society as a whole. Production techniques are inefficient and there is a reluctance to innovate and adopt modern methods of construction. The industry holds stocks of land for development which it does not bring forward quickly enough when prices rise, to deliver increased housing numbers. Housebuilders respond poorly to the needs of individual consumers resulting in a large number of complaints. The long-term upward trend in house prices and recent problems of affordability are the clearest manifestations of a housing shortage (Barker 2003).

Innovation (OSP) in the industry. There is a climate of change in the UK housebuilding industry. Offsite fabrication offers a solution to some of the new demands which present themselves (Housing Forum 2002). Despite the claimed advantages being compelling, they have had little impact in terms of the take-up in the sector.

Public resistance on OSP and design. Good design in housing results in social, economic and environmental benefits that support sustainable development and promote good citizenship and thus it must be a basic ingredient of every new-build and refurbishment scheme (Randall, 2003). As Sir Stuart Lipton, Chairman of the Commission for Architecture and the Built Environment (CABE), comments, "*Good housing design should embrace innovation and use modern methods of construction to produce high quality, durable and desirable homes*." However, following the design and structural disasters of housing built with industrialized methods in the 1960s and 1970s, a public nervousness persists about off-site manufacture and industrialised building methods (Randall 2003). Demonstrating that innovation in construction and good design are not mutually exclusive is then an important task.

Drivers & Barriers of Innovation (OSP) in UK Housebuilding

The literature reveals several key drivers for adopting OSP in housebuilding as addressing skill shortages, entertaining government and industry concerns, demonstrating 'Egan' compliance, and confirming to revisions to the building regulations. Barriers to OSP in housebuilding have been identified as historical failures, reluctance to innovate, unfavorable perceptions of stakeholders, and the existing culture of risk aversion. For a detailed review, please refer to Pan *et al* (2004).

Methodology

Initial research objectives and hypotheses were developed from the outcomes of the literature review outlined above. These initial objectives and hypotheses were explored within a set of interviews with designers in the industry. The aim was to use the exploratory interviews to shape and refine the research objectives. Six interviews were carried out with senior staff, which included four architects and two structural engineers. These exploratory interviews were semi-structured in nature with four guiding themes and lasted around an hour. The interviewees were encouraged to talk

openly about their experiences with OSP applications. The interviews were recorded and transcribed verbatim. The results of the interviews are analysed in such a way as to allow the comparison of views on different cases, either project or OSP techniques. Both results from the literature review and interviews were crossly discussed.

Results

The results are presented below under four themes as set in the interview guiding question list and are drawn from the analysis:

Theme one - Concepts of innovation and OSP

Innovation was claimed to embody new things, ways, approaches to problems, either in physical products or processes, or the changing of people's mind. The key characteristics of innovation were claimed as: to be new; to be practical and productive; to be easily integrated into existing process; to be incremental and sustainable. Most of interviewees agreed that OSP and innovation are overlapping – innovation includes some OSP techniques but much more, while part of OSP techniques have long been used. There remain many people who perceive OSP as experimental and associated with many uncertainties, especially cost.

Theme two – OSP in the UK housebuilding industry

Level 1 and 2 of OSP have been widely accepted and to some extent integrated into their business. However, interviewees claim they either feel reluctant to start to consider to adopt level 3 and 4 of OSP in terms of housebuilding. Most interviewees claimed they needed to be convinced of the advantages of OSP, particularly volumetric techniques.

Theme three – Exploring drivers for and barriers against OSP

Government promotion was claimed as the biggest driver for OSP applications. Cost and time certainties, short on-site duration, better quality, partly addressing skills shortages, better control of health and safety, clients' influences were also mentioned. Barriers against the take-up of OSP applications can be grouped into technical barriers and human barriers. *Technical barriers* include extra cost incurred, short lead time allowed, the need to freeze the design early on, site specifics or constraints, problems in achieving economies of scale, the fragmented structure of the housebuilding industry, insufficient manufacturing capability, and interfacing problems between systems. *Human barriers* included unfavourable attitudes from many architects and designers, the negative perceptions caused by a few recently built unfavourable OSP practices, the historical failure with prefabrication, skills shortages, misunderstanding on addressing skills shortages, lack of knowledge of adopting OSP, the risk averse attitude of most clients, and insufficient training on site levels. Human perceptions included aspects of technical, cost, the structural requirements associated with social, security, privacy and noise problems, and perceptions grounded in the historical failings of OSP technology. The underlying reasons for these human barriers were claimed as relating to: a lack of research, historical failures and recently built unfavourable projects, a lack of integration of project team and long-term cooperation and difficulties in planning in the long term.

Theme four - How to promote OSP applications

Some solutions to overcoming barriers against OSP were discussed. They were to get more demonstration projects to convince people of the benefits of OSP, to be more objective in briefing clients the advantages and disadvantages of adopting OSP, to improve training in installation techniques, to improve knowledge of stakeholders on OSP, to develop long term cooperation among stakeholders, and to address interfacing and tolerance issues.

Discussion

Drivers for and barriers against innovation (OSP)

Increasing the amount of OSP would form a logic method for incorporating lean production into construction project delivery which should facilitate the performance improvements called for by the Egan Report. However, the incorporation of OSP into the construction process is meeting significant resistance from both clients and many of their advisors (Pasquire and Connolly 2002). Edge *et al.* (2002) also claim, whilst there is no real technical barrier to increasing standardisation and prefabrication in housing, there may be a considerable amount of resistance to innovative housing amongst clients and the wider public. However, results from this study reveal technical and human barriers are highly integrated and the human perceptions exist in all stakeholders including clients and the public. Also, results of interviews reveal that OSP needs multi- and better- skilled workforce and it actually does not solve the skills shortages, but merely involves a transfer of skills from the site to the factory.

There is little understanding within the UK construction industry of the process of putting parts of construction into manufacturing. Design consultants have little understanding of the differences in designing for manufacture and assembly (DFMA) from designing for insitu assembly (Pasquire and Connolly 2002). The challenge is to encourage the changes required and this will only be achieved if all these benefits can be expressly valued and/or scored on a comparative basis. The decision not to use pre-assembly should be based on a true comparative evaluation and not, as so often happens on habit/tradition or first cost criteria (ibid). However, this only deals with those stakeholders who are directly involved in the project delivery (e.g. architects, clients, contractors) but not those who are indirectly involved (e.g. end-users, the public). It is because that they are unlikely to use any tools to do comparative evaluation but just focus on the product and its capital cost. Views from stakeholders involved in housing developments depict human perceptions as seriously affecting OSP applications. The human problem of managing attention and the strategic problem of institutional leadership in the management of innovation are discussed by Van De Ven (1986). People and their organisations are largely designed to focus on, harvest, and protect existing practices rather than pay attention to developing new ideas. Innovations not only adapt to existing organisational and industrial arrangements, but they also transform the structure and practices of these environments. The strategic problem is one of creating an infrastructure that is conductive to innovation. In this study, aspects of human, process and context are revealed as being much more complex. Human aspects involve all key stakeholders, process aspect includes the integration of OSP into project delivery process, and the context embraces aspects of time and spatial (Pan et al. 2004).

Appropriate strategies to facilitate OSP applications

The vast majority of innovation problems stem from a mismatch between technological possibilities and market demands. Different kinds of innovation are appropriate at different stages of a product life cycle. Managers must develop appropriate leadership styles and organisational configurations to facilitate each type. The particular innovation profile should be linked to the organisation's strategy, which should, in turn, be driven by an assessment of external opportunities and threats (Tushman and Moore 1988). Managing innovation involves mediating between external forces for change and internal forces for stability. Effective innovation over time involves developing the leadership styles and executive team that can create the conditions to facilitate both short-term efficiency and long-term adaptability. The manager and his or her team must develop their own learning abilities and, in turn, facilitate the organisation's ability to adapt. Organisation learning is at the heart of managing innovation (Van De Ven 1986). The development of an innovation demands close collaboration across the supply chain. This study is also to help the industry develop appropriate strategies and, in turn, appropriate structures, human resources, and cultures to facilitate sustained innovation.

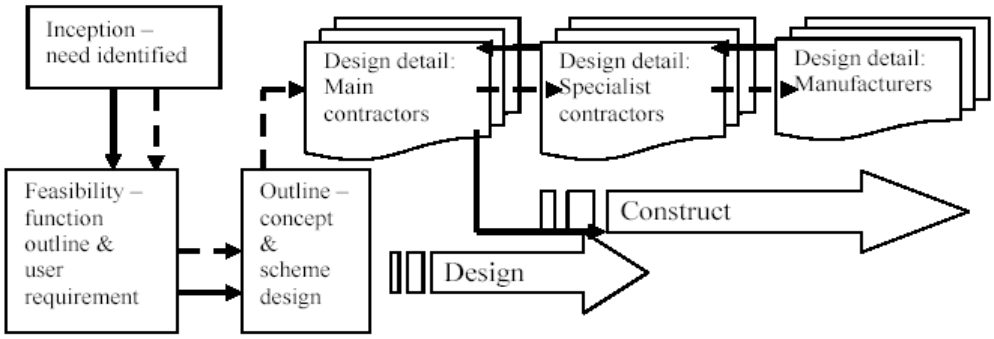
Not all design is carried out by architects and not all architects are instinctively brilliant designers. Some may find that their attempts to improve design quality thwarted by tight budgets or unsympathetic clients. There exists much attention on the design guidance from CABE and the Housing Corporation and it is claimed good design needs the support of clients and designers and good design must become a core ambition of housing associations if standards are to be raised (Keating 2004).

Much work has been done to define the benefits of OSP and identify the related drivers and barriers, one under-researched area is the re-defined design process with OSP integrated and the new role of designers. If the benefits of OSP are to be realised, appropriate integration into the design process must be carried out. Pasquire and Connolly (2003) develop a 3-step DFMA model (Design for Manufacture and Assembly) based on the case study with a major UK M&E contractor. Though it is from a M&E case study and focusing on M&E services installation, the analytical process from the traditional design process to the improved one can be referred to and is discussed in the following sections.

Traditional design process

Traditional procurement methods frequently permit or even requires, design activities to be undertaken by the contractor, who in turn can pass them on to sub-contractors and manufacturers. Detailed design activities eventually reside with those parties best qualified to undertake them. However, by the time this happens, the overall design process has progressed beyond the strategic and feasibility phases and this second and third hand design activity is continually playing "catch up" to the principal and original design team ideas (Figure 1). One outcome of this process is that the detail design is left to the last possible minute with little consideration being given to investigating the level of design detail already available in the market place at concept stage and how this might best be used to improve the project delivery (Pasquire and Connolly 2003).

Figure 1: Traditional design process

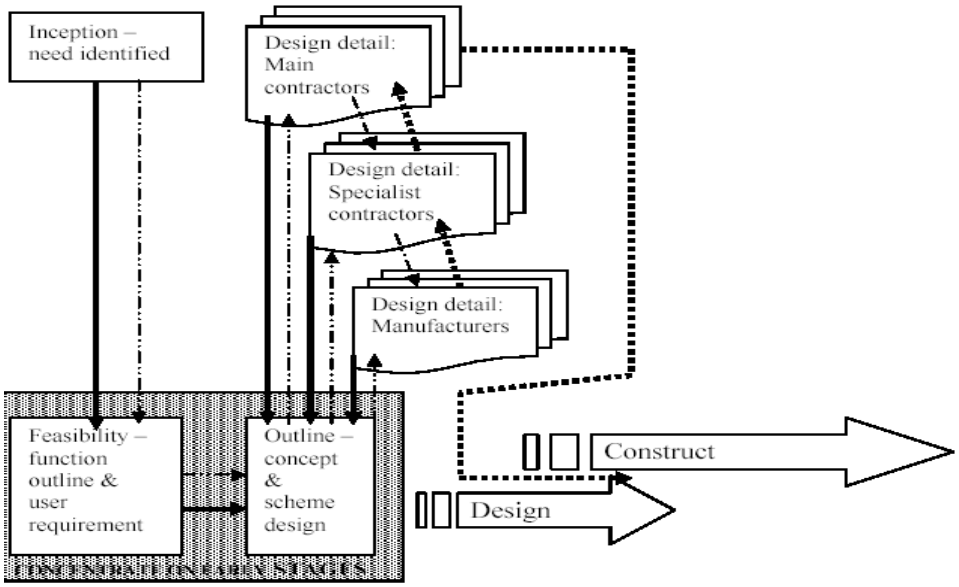


Adapted from (Pasquire and Connolly 2003)

Improved Design Process

The improvement of design practice must be driven from two directions, firstly the building designers themselves and secondly improvements within the manufacturers. The improved relationship is illustrated in Figure 2 where more emphasis is placed on the earlier stages to ensure a clear project strategy relating to client need (all focused on same client) with well defined project drivers and constraints. This change is results in two major requirements: designers leave detailed design to manufacturers and become experts in component specification and defining client/user experience; and manufacturers (including contractors) provide better product specification and take more care to understand client need and building design constraints. Pre-assembly is not a consideration that may be addressed at some point during the design process but a fundamental aspect of the design used as a matter of course and the consideration is then to identify where pre-assembly is not appropriate (ibid).

Figure 2: Improved design process



Adapted from (Pasquire and Connolly 2003)

A 3-step DFMA process has been consequently developed in this case for M&E services installations, which offers a more streamlined and less wasteful design

service for clients from consultants and manufacturers. This improved design process will result in more integrated and co-ordinated construction processes, increasing quality, reducing conflict and facilitating the drive towards Egan's seven targets for improvement (ibid).

However, the studies by Pasquire and Connolly is based on the M&E services case study. The integrating of manufacture and assembly into the design process inevitably embrace the considerations on its unique context, which might become constraints for the findings to be generalised. M&E tends to apply to the non-domestic market which is a fundamental difference from this paper. Also, the studies oversimplify the factors of consideration for the appropriate integration and there are actually wide range of barriers from technical, human, industrial and historic aspects which are incorporated together and inhibit the integration of OSP.

Conclusions and Further Research

Despite being claimed as a solution to the housing undersupply, the OSP applications in housing lag behind what they should be and the industry has remained reluctant to take up innovative OSP techniques. This paper has reviewed the concepts of innovation and OSP within the context of the UK housebuilding industry and explored the drivers for and barriers against the uptake of OSP and its integration into the design process. The findings of the literature review and exploratory interviews reveal that technical and human barriers are highly integrated and inhibit OSP applications, and human perceptions grounded in the fragmented industry structure and the risk averse culture have stymied developments in this area. Good design can provide benefits in aspects of social, economic and environmental etc. and OSP techniques have to be appropriately integrated into the design process if the benefits of OSP are to be realised.

This paper forms part of an on-going study which aims to explore the successful integration of OSP in the UK housing sector. The focus of this paper on the perspectives of design professionals do not imply the perspectives of manufacturers and suppliers, clients and end-users, and contractors etc. are not or less important, but contribute to the knowledge by which the industry will be encouraged to speed up the OSP uptake. Based on this paper, several case studies will be used out to further explore the interactive relationships among the wide range of barriers against the adoption of OSP techniques in the UK housebuilding. Such knowledge should enable strategies to be developed to overcome human and perceptual barriers to innovation in OSP within the housebuilding sector.

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