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
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Constraints to the use of off-site production on construction projects

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Abstract

Offsite production (OSP) has been promoted as one of the solutions to the industry's performance problems. Numerous works have demonstrated the possible benefits from adopting such approaches to construction projects, yet uptake has been slow. Addressing these concerns a series of factors were identified that affect the use of OSP within construction projects. From these factors a pattern emerged in which some factors drove OSP adoption, whilst others constrained its implementation. These constraints were investigated further using a questionnaire survey that was sent to all major stakeholders, ranging from clients through to end manufacturers. The extent to which the constraints inhibit the use of OSP were ascertained, scored and ranked. Four broad constraint themes emerged from the findings, namely process, value, supply-chain and knowledge constraints. A model illustrating the relationship between the four themes provides further insight into the constraints to OSP uptake. The authors further suggest that a broader understanding of the constraints is required, arguing that while OSP can contribute to change in the industry, it itself depends on change in order to be widely adopted.

Keywords: constraints, mitigation, off-site production, pre-fabrication, value

Introduction

Recent UK government reports, including the Egan Report “Rethinking Construction” (1998), produced by the Construction Task Force, discussed the need for performance improvements in the UK construction industry. Egan (1998) identified supply chain partnerships, standardisation and off-site production (OSP)¹ as having roles in improving construction processes. However, the uptake of OSP in construction is limited despite the well documented benefits that can be derived from such approaches (Neale *et al.*, 1993; Bottom *et al.*, 1994; CIRIA, 1999, 2000; Wilson *et al.*, 1999; Housing Forum, 2002; Gibb & Isack, 2003).

The use of OSP, by many of those involved in the construction process, is poorly understood (CIRIA, 2000). Some view the approach as too expensive to justify its use, whilst others view OSP as the panacea to the ills of the construction industry’s manifold problems (Groak, 1992; Gibb, 2001). Yet others see construction as unique in nature, possessing characteristics and problems innate to the industry, which severely inhibit the application of manufacturing principles (Nam & Tatum, 1988). None of these views is necessarily appropriate. A pilot study demonstrated that decisions to use OSP are still largely based on anecdotal evidence rather than rigorous data, as no formal measurement procedures or strategies are available (Pasquire & Gibb, 1999). OSP is hindered by the industry’s inability to appreciate the benefits, and also the inherent constraints of the approach.

Research undertaken by CIRIA (1999, 2000) identified a series of factors that affect the use of OSP within construction projects. Among these factors were a number identified as constraints to the implementation of OSP. The distribution and effect of these constraints within the industry, were however ill-understood. This paper discusses the results of a questionnaire survey that investigated the impact of CIRIA’s constraints on the implementation of OSP within the construction industry. A model of the interaction between constraints is developed through the paper and discussed with specific reference to their mitigation. The following sections elaborate on the derivation of the constraints and the methods used for the questionnaire survey.

Constraints to OSP Implementation

The formative research (Gibb and Isack 2001) for the development of the Standardisation and Pre-Assembly - Client’s Guide and Toolkit² (Gibb 2000) investigated client/owner drivers to help

understand their implication on the pre-contract decision making process. The research found that client's want value for money in terms of:

- Lowest whole life cost
- Lowest cost for a given quality
- Satisfied end users
- Highest quality for a given cost
- Consistent quality

Further research (Gibb and Isack 2003) qualified those drivers in terms of what clients see as the benefits of off-site production i.e. cost, time and quality. For the Client Guide and Toolkit (CG&T) they were extended to include the terms profitability, predictability and productivity. Gibb and Isack (2003) noted that client's also perceived disadvantages to OSP and noted in particular:

- Some products are poorly built
- Some contractors are not experienced enough
- Some original designs do not suit offsite
- Some sales teams were over ambitious
- Many solutions had a high initial cost
- Supply chains were often inadequate
- There was a low volume of work

It was clear that where there were advantages, there were also disadvantages. Those attributes were then used to engage invited design professionals during workshops as part of a CIRIA\Loughborough University demonstration project for the UK government.

Originally the demonstration project objectives were to:

- Test the Client Guide and Toolkit (CG&T) on live projects
- Examine the response of industry
- Deliver a revised toolkit that addressed those findings
- Provide a final output deliverable in the form of an interactive CD

During formative workshops, the merits of OSP were debated and the applicability of the toolkit questioned. These workshops involved an assembly of key individuals, strategic thinkers able to use the input from the literature search and review to hone project definition and flush-out the appropriate issues. One of the findings was the existence of a close similarity in the project drivers for both traditional and OSP techniques. What stood out as missing and what construction professionals needed was an appropriate balance to the CG&T's pro-OSP bias. Working together

with the research team they found that by identifying disadvantageous project attributes and aligning them against the project drivers a project strategy started to evolve.

The initial research also found that most design professionals were already aware of the benefits OSP offered to them. They were not looking for an educational tool but were looking for a tool to help determine viability and influence the outcome from applying OSP techniques on their particular project. They required this tool to:

- Help with the creation of a project strategy,
- Assist in the measurement of benefits from the implementation of that strategy.

A close examination of how the CG&T presented its information was made; the output of that examination was brainstormed with an industry led focus group to establish the best way to respond to the identified needs. The toolkit was then redesigned into a format that delivered background, strategic and measurement advice.

The redesigning of the CG&T necessitated a change in the way its information was accessed. It was decided to restate original project driver sets of cost, time and quality and in addition create sub-sets to accommodate the major variables under those headings. These drivers would be used in the initial creation of the project strategy. It was noted that the verified list of benefits in the original CG&T provided both positive and negative benefits for OSP and it was these attributes that would determine the use of OSP on a project. The positive influences evolved into the driver subsets and the negative influences were termed constraints to the process. Initially these were presented as a list of twenty two constraints. These constraints being the most likely to inhibit implementation of OSP on a project or reduce the likelihood of achieving the potential benefit when applying OSP techniques now required testing and confirmation from industry. Further workshops with construction clients and their designers were convened to examine the new toolkits conformity to their brief. Some beneficial changes were made, like the addition of environmental issues and moving some drivers to the constraint section.

The list was again presented to the focus group for them to negotiate both context and meaning before re-presenting the proposed mark two version of the toolkit to designers. Some reviewers missed a systematic layout that was employed in the drivers so a set of headings were provided to separate out the constraints into site constraints, process constraints and procurement constraints. The final negotiated list is given in Table 1.

Although a rigorous set of constraints had been identified by the CG&T workshop groups, there lacked a measure of their influence on OSP within the broader UK construction industry. As part of another related research project at Loughborough University, a questionnaire survey was undertaken to gauge the industry's perception of where the main constraints lay within the industry. From this data a higher level model of the constraints on OSP use could be developed. The following section describes the survey results.

Table 1: List of Drivers and Constraints

DRIVERS		CONSTRAINTS	
Cost Drivers		Site Constraints	
D1	Ensuring project cost certainty	C1	Restricted site layout or space
D2	Minimising non construction costs	C2	Multi trade interfaces in restricted work areas
D3	Minimising construction costs	C3	Limited or very expensive available skilled on-site labour
D4	Minimising overall life cycle costs	C4	A problem transporting manufactured products to site
Time Drivers		C5	Live working environment limits site operation
D5	Ensuring project completion date is certain	C6	Limitation to movement of OSP units around site
D6	Minimising on-site duration	C7	Site restricted by external parties
D7	Minimising overall project time	Process Constraints	
Quality Drivers		C8	Short overall project time scales
D8	Achieving high quality	C9	Unable to freeze design early enough to suite OSP
D9	Achieving predictability of quality	C10	Limited capacity of suppliers
D10	Achieving performance predictability throughout the lifecycle of the facility	C11	Not possible for follow-on projects to use the same processes
Health and Safety Driver		C12	No opportunity for component repeatability on this or future projects
D11	Reducing health and safety risks	Procurement Constraints	
Sustainability Drivers		C13	Project team members have no previous experience of OSP
D12	Reducing environmental impact during construction	C14	Obligated to work with a particular supply chain
D13	Maximising environmental performance throughout the lifecycle	C15	Not willing to commit to a single point supplier
D14	Implementing Respect for People principles	C16	Obligated to accept lowest cost rather than best value
		C17	Key decisions already made preclude OSP approach
		C18	Limited expertise in off-site inspection
		C19	Early construction/manufacturing expertise and advice unavailable
		C20	Obligated to accept element costing based on SMM

Survey Results

A questionnaire survey was undertaken to understand the particular areas within the broader construction process that constrain the implementation of OSP on building projects. The

questionnaires comprised of the drivers and constraints listed in table 1, against which respondents could indicate, on a Likert scale, their responses to the questions posed. Among the questions, respondents were asked what the likely impact was on using OSP for each of a given series of process and procurement constraints.

Two hundred and eighty nine (289) questionnaires were mailed in December 2002 to a sample comprising the IMPREST (Interactive Method for Measuring PRE-assembly and STandardisation benefit in construction) project mailing list (Blismas *et al.*, 2003), Lean Construction Network mailing list, and the delegates of The Way Forward Conferences (Manufacturing the Future, 2002)³. Seventy three (73) replies were received, representing a 25.3% response rate. The responses were received from a wide spread of groups within the construction team, ranging from clients, consultants and through the entire supply-chain. Figure 1 illustrates the spread of responses according to roles within the industry. Significantly, the proportion of specialist suppliers was only 15%, diminishing the possibility that the results were biased by their desires to portray OSP as a highly beneficial solution to construction projects.

A simple profile of respondent's experience with using OSP also revealed that approximately two-thirds had moderate to high experience of using OSP in construction. This majority ensured that the responses were based on actual experiences and not on expected outcomes that suppliers of OSP products claim. Figure 2 graphically depicts the level of experience with OSP by respondents.

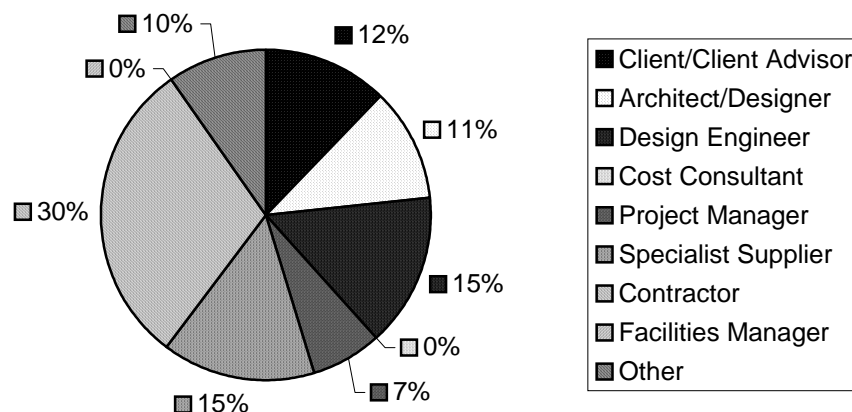


Figure 1: Chart illustrating the distribution of survey replies according to respondent's roles.

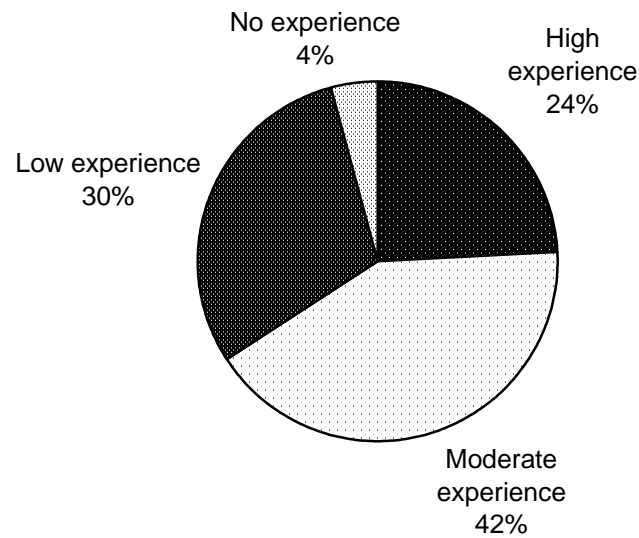


Figure 2: Chart illustrating the distribution of survey replies according to respondent's OSP experience.

Responses to the questions regarding the various process and procurement constraints were scored according to the responses selected on the Likert scale. Responses at either extreme were weighted to enhance their significance within the results. Table 2 provides the points used to score each constraint response. Each constraint was then scored and ranked from lowest to highest scores, reflecting the constraints that most hinder OSP implementation and use. Figure 3 displays the individual hindrance and benefit, as well as total, scores for each constraint that constituted the final points used for ranking.

Table 2: Scores used to weight the questionnaire responses.

Likert Scale option	Score
Significant hindrance to using OSP	-3
Moderate hindrance to using OSP	-1
No impact	0
Moderate benefit to using OSP	1
Significant benefit to using OSP	3

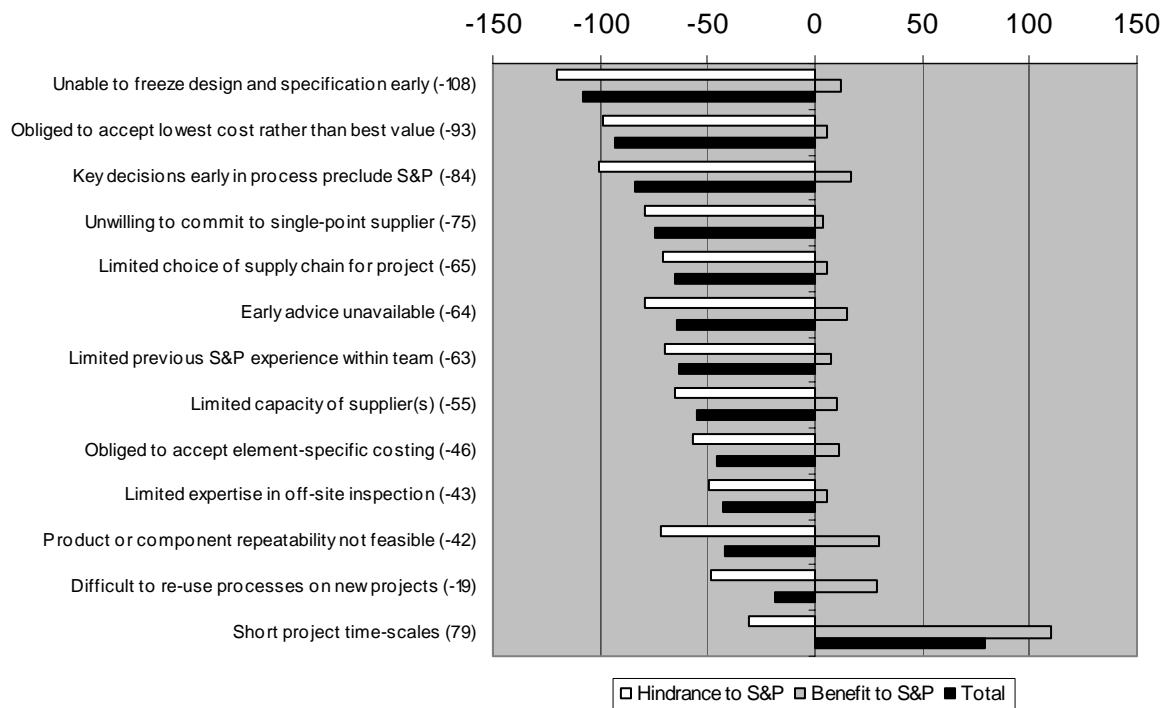


Figure 3: Constraint scores depicted as hindrances and benefits to OSP implementation. Scores were derived from survey results and are ranked according to their total scores shown in brackets against each constraint.

Analysis of Constraints

An overview of the ranked constraints presented in figure 3 shows that time and cost issues are identified within the top three factors most hindering OSP implementation. Being the most familiar of project related factors, they are expected to rank highly in any questions regarding project constraints. Early decisions and a value-based approach appear to be the two greatest issues hindering OSP. Attendance of these two issues within projects would certainly mitigate the conditions that hinder OSP. However, viewing these constraints in isolation does not provide the necessary context to allow the formulation of effective OSP strategies for organisations and project teams. Taking a broader view, this section discusses constraints within themes that are modelled to reveal the broader issues hindering OSP implementation.

The constraints were grouped into four broad themes. Using cumulative hindrance scores and averages as indicators of relative importance between themes, revealed significant changes to constraint emphasis. Table 3 lists the themes and their constituent constraints, including individual,

cumulative and average scores. Each theme is discussed individually within this section. A model of their interaction is developed in the following section.

Process

The main constraint to OSP implementation and use is the client's or designer's inability to freeze the design and specification early enough within the construction project process. This constrains the manufacturing process from proceeding concurrently with other works in order to ensure that delivery of the component is made when required on-site. Ordinarily, clients and designers have some freedom to develop designs and make changes during the construction phase of a traditionally-procured facility. Changes to design, within the construction phase of a project, affect efficiency levels regardless of the building method. However, the effects on OSP are more pronounced due to the differences in the project process. Forcing clients and their teams to concentrate on design fixity would significantly improve the project conditions for the use of OSP. The authors also argue that a better understanding of design fixity would realise benefits for all construction projects whether or not using offsite techniques.

Surprisingly, the least influential constraint of short project time-scales is very closely linked to this constraint. Suggestions that OSP cannot deliver solutions within short project timescales is dismissed by the data – indicating that the prime issue is early decision-making rather than one of overall project timescale. The constituent constraints of this theme strongly indicate that the main hindrance within the construction process to OSP is a lack of early and firm decisions of design and specification.

Table 3: Constraint themes ranked by cumulative hindrance scores, illustrating the broader constraint issues of OSP.

Theme	Constraint	Score	Cum. Score
Process Constraints	Unable to freeze design & specification early	-108	-113
	Key decisions early in the process preclude OSP	-84	
	Short project time scales*	79*	
Value Constraints	Obligated to accept lowest cost rather than best value	-93	-139
	Obligated to accept element-specific costing	-46	
Supply-chain Constraints	Unwilling to commit to single point supplier	-75	-195
	Limited choice of supply-chain for the project	-65	
	Limited capacity of supplier(s)	-55	
Knowledge Constraints	Early advice unavailable	-64	-231
	Limited previous OSP experience within the team	-63	
	Limited expertise in off-site inspection	-43	
	Product or component repeatability not feasible	-42	
	Difficult to re-use process on new projects	-19	

* Results would indicate that this factor is not a constraint, but a driver of OSP.

Value

An obligation, set by clients, to accept lowest cost options rather than best value, was indicated as the second highest individual factor hindering OSP implementation. Taken in conjunction with the associated constraint of element-specific costing, the theme demonstrates that the entire issue of value and its measurement are impediments to OSP use. An associated study within the research project demonstrated that choices between traditional and OSP elements were overwhelmingly based on simple cost estimates. Common methods of evaluation simply take material, labour and transportation costs into account when comparing various options, often disregarding other cost-related items such as site facilities, crane use and rectification of works. These cost factors are usually buried within the nebulous preliminaries figure, with little reference to the building

approach taken. Further, softer issues such as health and safety, effects on management and process benefits are either implicit or disregarded within these comparison exercises.

The inadequacies of current evaluation systems are a major constraint to OSP implementation within construction. On a simple cost basis, OSP options will often appear more expensive than their traditional alternatives; however a more holistic value-based approach would highlight the advantages of OSP not readily convertible into monetary terms. IMPREST (Blismas *et al.*, 2003), an interactive toolkit that was developed to facilitate the evaluation of benefit arising from use of OSP, uses different facets of value rather than relying solely on monetary measures. It moves the focus away from cost alone to a raft of other benefits that should be evaluated before deciding between different building methods. It provides the stimulus for project teams to look beyond 'lowest cost' and 'element-specific costing' when planning projects.

Supply-chain

The third group of constraints are those imposed by supply-chain issues. One of the main constraints to OSP, an unwillingness to commit to single-point suppliers, is a risk averting measure. Suppliers of OSP solutions are usually specialists who may therefore be the only available suppliers to a project. In addition, the longer lead times required for OSP products means that a change of suppliers after the design fix stage can be very complex. A high degree of trust would be required by the client team to place orders for OSP elements with a single point supplier. However, the data suggests that such trust within the industry is required for OSP solutions to be explored and employed more often within building projects.

Corollary constraints to that of spreading supplier risk are those imposed by limitations to supplier choice and capacity. The slow development of the OSP market has resulted in a relatively small choice of suppliers from which clients can select. In addition, these suppliers often have relatively low production capacity for large projects or periods of market growth. The general structure of the supply market and clients' attitudes towards it, have a significant impact on OSP implementation.

Knowledge

The final theme contains the largest number of constraints, although these were generally scored more moderately than other constraints. It is recognised that much of the hindrance to OSP stems from limited experience in the use of the approach within the industry. Knowledge and experience of OSP within project teams encourages the investigation of OSP building options that perhaps would not normally be considered.

This group of constraints clearly demonstrate that knowledge input is required throughout the construction project process. Advice is required at the early conceptual and developmental stages, within the construction team in the design and build stages, and for off-site inspections during manufacture. In addition, product and process re-use on new projects stems from experience and knowledge gained by previous OSP projects. Seen holistically, this group of constraints influences all other themes discussed above.

The following section draws these four themes together into a high level model that forms the basis of a strategy to mitigate constraints on OSP implementation.

Mitigating OSP Constraints

The successful completion of a construction project, whether using OSP or traditional approaches, depends on the clear identification of the key factors driving the project, as well as an appreciation of the constraints affecting its efficient completion (Gibb & Isack, 2001). However, within the broad group of factors that constrain projects, specific factors particularly limit OSP implementation. Identification of these, and steps to ensure that they are mitigated, will ensure that evaluation of the benefits possible through OSP can be realistically achieved. These constraints can be addressed on two levels, at the individual micro level and the broader macro level.

Where constraints are easily identifiable and prominent, individual mitigation is possible. However, it is more probable that projects will have a mixture of constraints that all impact OSP implementation to varying degrees. Attempting to mitigate these individually would be difficult and inefficient, as they are intricately related with the wider organisational culture. Organisational level initiatives that tackle groups of constraints simultaneously would be of greater benefit. Many of these issues are addressed by the recommendations and consequent initiatives of Rethinking Construction (Egan, 1998). The report's focus on process, integrated teams, supply-chains and value, all would largely alleviate constraints on the use of OSP.

Taking the constraints identified, ranked and grouped above as a basis, a model of these themes is developed which maps the issues and the main steps needed to mitigate them. The hindrance scores given to each constraint within the questionnaire (figure 3) shows that issues which are more prominent within construction are scored more highly than those that may be implicit in nature. As discussed above, cost and time feature highly, whereas process repetition and knowledge score low. However, it is argued that addressing these less prominent constraints will have a direct impact on the more prominent constraints.

A simple model was constructed (figure 4) to illustrate the relationships that exist between the various constraint themes. Client perception of value (a) ultimately drives an entire project, dictating the criteria by which a project should be delivered. Usually these are monetary, but increasingly, softer issues are impinging on client project values. Client values therefore set the tone for an entire project, influencing the method of delivery. Cost minimisation as a driver may yield a different procurement method to one of sustainability. Given appropriate experienced input at the outset, the client can pinpoint the main project drivers based on the organisation's strategic goals.

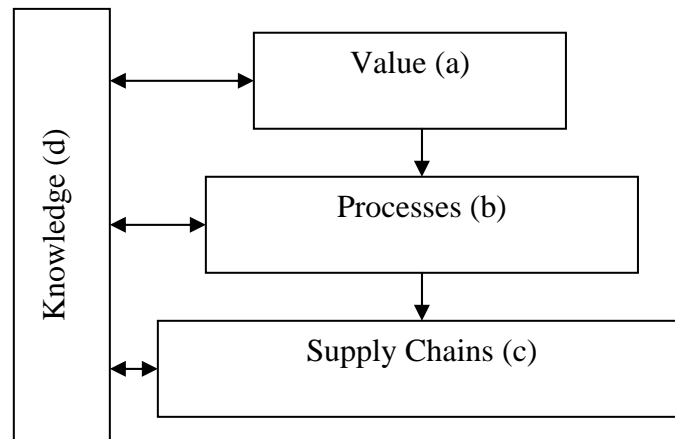


Figure 4: Simple model mapping the interaction between various aspects of OSP constraints.

Processes (b) therefore, are influenced by the factors that hold greatest value to the client. Explicit value for the client should provide an appropriate process that will deliver those desires. However, an understanding of the link between the two levels is required to ensure that they are appropriately aligned. Determining the process and the decision-gates are important steps in focussing the client and project team's efforts towards enabling the efficient implementation of OSP on a project. Input from persons with experience in OSP is vital to ensure that processes are sustained by timely decisions.

Supply-chain (c) management styles are linked to processes. Procurement routes, processes and supply-chains are all linked within a project to deliver the values specified by the client. Supplier capacity, selection and relationship all hinge on previous decisions and processes. Again,

individuals or teams experienced in dealing with specialist or single suppliers would be able to advise on the structure and management of supply-chains so as not to hinder OSP use.

Common to all the themes discussed above is the need for knowledge (d) input, as illustrated in figure 4. Analysis of the individual knowledge constraints shows how these cover the entire spectrum of activities from project inception through to manufacturing inspections. Table 4 shows how each of the constraints contained within the other themes is affected by knowledge.

Table 4: The influence of knowledge on OSP constraints.

Constraints	Knowledge
Unable to freeze design & specification early	<ul style="list-style-type: none"> ▪ Early advice to the client and design teams would encourage design freeze by explaining the consequences to OSP solutions, ▪ Experienced advisors and team members are able to guide the client and design team to a freeze more quickly, thereby enhancing conditions for OSP implementation,
Key decisions early in the process preclude OSP	<ul style="list-style-type: none"> ▪ Early advice by experts in OSP would ensure that initial designs and decisions do not preclude the option of using an OSP solution, although OSP should ideally be included in the design from inception,
Obligated to accept lowest cost rather than best value	<ul style="list-style-type: none"> ▪ Early advice by experienced persons could influence the client and other advisors to evaluate the project in terms of value and not simply build cost, ▪ OSP knowledge within the team and advisors will be able to highlight the benefits of OSP options both in monetary and non-monetary terms,
Obligated to accept element-specific costing	<ul style="list-style-type: none"> ▪ As above, non-element costing would allow the project team to view all building aspects in terms of value and not simply cost,
Unwilling to commit to single point supplier	<ul style="list-style-type: none"> ▪ OSP experience in the team and advisors will grant the client confidence to commit to single-point suppliers should the project require, ▪ Use of past relationships with suppliers will also give the team confidence to place orders with a single supplier, ▪ Expertise in off-site inspection, to monitor off-site manufacture quality and progress, adds further confidence to the team to commit to a single-point supplier should the need arise,
Limited choice of supply-chain for the project	<ul style="list-style-type: none"> ▪ Early advice may enlighten the client to search for possible suppliers more broadly, ▪ Contacts made through previous contracts including OSP may prove valuable in accessing suppliers with appropriate skills and knowledge,
Limited capacity of supplier(s)	<ul style="list-style-type: none"> ▪ Early advice, decisions, and therefore negotiations with key suppliers may permit earlier start to production, thus alleviating capacity problems,

Mitigation of the constraints obstructing the use of OSP on construction projects should be addressed on the macro-level by increasing the level of knowledge input into all levels of the

project process. Experience in OSP is necessary to drive constraint mitigation at the macro-level, whilst specific tactics can be employed to deal with constraints at the micro-level. However, it is argued that without the necessary expertise, even these micro-level initiatives will not yield their potential success as tactics will be borne out of a lack of knowledge.

Conclusion

The challenges facing the industry are essentially knowledge-related. These relate to methods of generating, obtaining, and disseminating expertise on OSP evaluation, manufacture and use. The toolkits, mentioned within the paper, offer some contribution to alleviating the knowledge gap, however the results presented suggest deeper issues are constraining the use of OSP in construction. Offsite research, including this study, has largely concentrated on project-level issues. Insufficient attention has been devoted to adequately exploring the wider economic, social and environmental issues surrounding OSP.

The industry has largely been recognised as one that is disjointed, underachieving, working at a low profitability, investing too little capital in research and development (R&D) and training, and generally leaving clients dissatisfied with performance (Egan, 1998). Further reports, such as Agile (1998), concur with these findings identifying poor leadership, risk averseness, fragmentation (Bauml, 1997), poor project flow and a non-value oriented approach to procurement as the main performance problems. The contradiction lies in that the very environment and culture OSP has been promoted as being able to change, is itself inhibiting OSP adoption and success.

Other underlying inhibitors of OSP adoption may lie within the issue of labour in construction. Green & May (2002) for instance argue that promotion of OSP serve to justify shifts towards labour-only sub-contracting and the associated reduction of employment rights. Such 'mechanistic' attitudes have implications on labour, businesses and society at large. Paradoxically again, the skills shortages that are driving many business cases towards using OSP, are possibly reasons for deterring people joining the industry.

The study has highlighted the project-level constraints on the use of OSP in construction. These were grouped into four broad themes that covered the array of specific constraints identified in previous research. The constraint themes were ranked using cumulative scores and arranged into a model that explained the relationships between the themes. Most prominent were process constraints, followed by value, supply-chain and knowledge constraints. Steps to mitigate the constraints were suggested in the paper, although these have larger implications than simply

encouraging OSP on a project. They affect procurement, teams, culture, professions, and many other aspects. The benefits of OSP cannot be realised until a more holistic view of the factors affecting its use are understood. It is unlikely that OSP can effect any changes in the industry until change first takes place to create an environment conducive to its successful use.

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Endnotes

1. Off-site production (OSP) can be defined as the completion of substantial parts of 'construction' works prior to their installation on-site. It replaces previously common terms such as pre-assembly and pre-fabrication. There are numerous levels of OSP, from pre-assembled sub-elements to whole buildings. A further discussion of these levels is given by Gibb and Isack (2003).
2. This was the deliverable from a UK government funded project.
3. The Way Forward for off-site construction in the health, social housing and education sectors. Organised by Manufacturing Change, National Motorcycle Museum, Solihull. 5-7 November 2002.

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Nick joined RMIT University as a Research Fellow in 2004 after completing his PhD and several research projects at Loughborough University in the United Kingdom. Prior to his academic career Nick worked as a project coordinator on a large multiple project programme in Southern Africa. His research interests include multi-project and programme management, occupational health and safety, off-site production and free-form construction.

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Martyn is currently a Research Associate in the Department of Civil and Building Engineering, Loughborough University. He completed his PhD at the same university in 2000 on Design Management with a thesis entitled *Techniques and Strategies to Improve Conceptual and Schematic Design*. Martyn has since specialised in off-site production, occupational health and safety and free-form construction research. Prior to taking-up an academic career he had worked in the construction industry for a period spanning over 25 years.

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Alistair is a Chartered Engineer and Chartered Builder and Professor in construction technology and management at Loughborough University, UK. He is Director of the industry sponsored Construction Engineering Management Programme and teaches on undergraduate and post graduate programmes in Construction Management, Civil Engineering, Commercial Management and Quantity Surveying. He has research expertise in collaborative projects with industry, including construction applications of manufacturing methods, standardisation, pre-assembly, health & safety, interface management and complex building facades.

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Christine is a chartered quantity surveyor with experience in both client and contracting organisations, becoming a lecturer in 1989 after completing her PhD at Loughborough University. She is Director of the MSc Programme in Mechanical & Electrical Project Management; and Senior Lecturer in Commercial Management & Quantity Surveying; responsible for delivering much of the Departments Construction Economics and cost related subjects including Life Cycle Costing and Lean Construction.