OFF-SITE PRODUCTION: EVALUATING THE DRIVERS AND CONSTRAINTS

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ABSTRACT

The decision making process used to evaluate to what extent a component or building system should be produced off-site is inadequate within the industry. Whilst the potential benefits of off-site production (OSP) are commonly cited when justifying an OSP approach, no clear method for assessing the applicability and overall benefit of these solutions exist. 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. Additionally, the factors that affect the suitability of OSP as a design solution are not formally defined, these are the factors that drive and/or constrain the design decision making. Case based research funded by the UK Engineering and Physical Sciences Research Council and Department of Trade and Industry in collaboration with eleven companies sampling over 200 people employed within the construction industry, examined these issues and developed a toolkit under the name IMMPREST[4]. This toolkit facilitates the evaluation of the potential benefits of choosing one approach over the other.

KEYWORDS

Pre-assembly, off-site production, drivers, constraints, benefits, measurement, value

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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) 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; BSRIA, 1999; Housing Forum, 2002; Gibb & Isack, 2003). A major reason for the reluctance among clients and contractors to adopt OSP is that they have difficulty ascertaining the value that such an approach would add to a project.

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). Neither of these views are necessarily correct. 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). The research undertaken for IMMPREST identified that OSP is hindered in the UK by the industry's perception that value is best ascertained using traditional rate-based measuring systems, focussed entirely on cost. Softer issues such as health and safety, sustainability, and effects on management and process are either implicit or disregarded within their evaluations. Choices between off-site and site-based production for building elements are therefore both imperfect and imprecise.

The greatest challenge facing construction practitioners is that of achieving the balance between effort expended to predict benefits and the value provided by the evaluation method employed. The advantages of evaluating benefit in monetary terms are that they can be closely linked to profitability, and compared directly with other financial measures. However, monetary measures are inadequate for items that cannot be directly attributable to an element, such as health and safety, or sustainability and wider human factors. Reducing all such factors into costs involves a large degree of speculation, which renders the final cost figure highly uncertain. A comparison between such uncertain figures will not provide any level of confidence to decisions derived from them. Essentially such exercises are no different from scoring systems to which numbers are assigned so that a final numerical, and 'objective', albeit questionable, outcome is produced. A more formal approach to measurement method was developed and incorporated into an evaluation system (Blismas et al 2004) for the IMMPREST toolkit.

This paper describes the IMMPREST benefit evaluation methodology for use by those deciding between traditional and OSP alternatives detailing the factors that drive and/or constrain the design decision making process and the data required to fully evaluate the options available.

ANALYSIS OF MEASUREMENT METHODS

Blismas et el (2004) analysed data from six cases comparing traditional with off-site produced building solutions (12 sets of cost data in all) and found only three cost items

		Labour costs	Material costs	Small Plant, tools & equipment costs	Transport, distribution & installation costs	Commission & Test costs	Design, planning & tender costs	Time & Process management	Health & Safety	Rectification & rework costs	Quality	Overhead costs	Package & storage costs	Life-cycle costs	People & human resources	Environmental impact	Logistical issues	**Total number of ✓**	**Total number P *or* I**	**Total**
Case A	Traditional	✓	✓	P	✓	✗	✗	✗	✗	✗	✗	P	✗	✗	✗	✗	✗	3	2	16
	Pre-assembly	✓	✓	✗	✓	✓	✓	✓	✗	✗	✗	✓	✗	✗	✗	✗	✗	7	0	16
Case B	Traditional	✓	✓	P	✗	✗	✗	✗	✗	✗	✗	P	✗	✗	✗	✗	✗	2	2	16
	Pre-assembly	✓	✓	P	✗	✗	✗	I	I	I	I	P	✗	✗	✗	✗	✗	2	6	16
Case C	Traditional	✓	✓	✓	✓	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	7	0	16
	Pre-assembly	✓	✓	✓	✓	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	7	0	16
Case D	Traditional	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	I	✓	✓	✓	✗	✓	14	1	16
	Pre-assembly	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	I	✓	✓	✓	✗	✓	14	1	16
Case E	Traditional	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗	?	✗	✗	✗	✗	✗	2	0	16
	Pre-assembly	✓	✓	✗	✓	✗	✓	✗	✗	✗	✗	✓	I	✗	✗	✗	✗	5	1	16
Case F	Traditional	✓	✓	I	I	✗	✗	✗	✗	✗	✗	P	I	✗	✗	✗	✗	2	4	16
	Pre-assembly	✓	✓	I	✓	✗	✗	✗	✗	✗	✗	P	I	✗	✗	✗	✗	3	3	16
Total number of ✓		12	12	4	8	5	6	5	2	2	2	2	2	2	2	0	4	68		
Total number of P *or* I		0	0	5	1	0	0	1	1	1	1	7	3	0	0	0	0		20	
Total		12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12			192

P = included in the prelims; ✓ = explicitly specified in cost or benefit comparison; I *= implied or mentioned in documentation; ✗ = apparently excluded from cost or benefit comparison; ? = information unavailable*

Table 1: Analysis and cross-case comparison

consistently included in each evaluation. The cross-case analysis of cost categories (Table 1 above), clearly demonstrates the emphasis of assessments. Labour, materials, and transport are pre-eminent in all cases. Transport is a more prominent factor in OSP considerations as the finished volumes raise issues of both cost and logistics, among others. However, apart from these three explicitly included cost items, all other issues are evident in less than half the cases of the study. Soft issues such as healthy, safety, quality, human and environmental factors are almost totally excluded. Important, and usually overlooked cost items relating to quality, such as rectification are generally included within the totals and are implicitly accounted for in the 'claims' that will be negotiated at the end of the project.

Table 1 above clearly demonstrates the predominance of the use of simple monetary measures that can be easily grasped and calculated as the basis of decision making. This misses opportunities to account for factors that contribute to value and supports the need for an altered approach to benefit evaluation to address the broader needs of the construction industry.

BENEFIT EVALUATION MODEL FOR OFF-SITE PRODUCTION

In order to assist the analysis of benefit measurement methods further, a categorisation model has been developed that comprises of two aspects of measurability, identified as hard-soft and simple-complex, illustrated in Figure 1 and explained in Table 2:

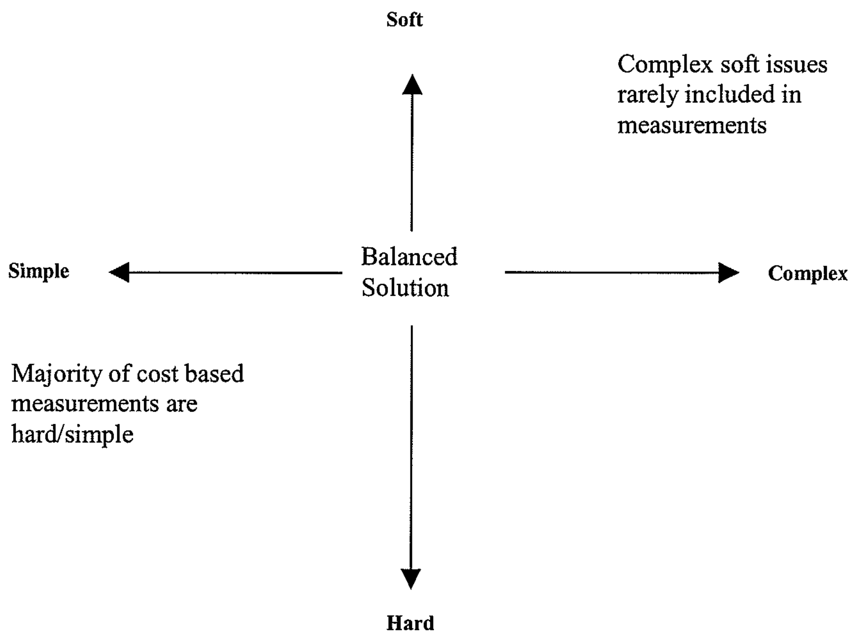

Figure 1: Model of Measurement Approaches

Generally, methods employed within the construction industry to evaluate various building approaches can be categorised into one of the quadrants of the model in Figure 1. Classic cost-based methods, for instance, fall within the bottom half of the model, while undocumented or implicit decisions tend to fall into the upper half of the model. The reason for this appears to be that the industry is still highly influenced by the historically powerful tendering framework, in which tenders are assessed and decisions made primarily on the grounds of cost and time. Historical roles, such as quantity surveying impose a strong influence on consultants and thereby clients, while suppliers do not usually have the resources to conduct detailed option analysis for each element of a building, given the high possibility that the work will not be awarded. The solution developed for IMMPREST was a method of measuring benefit that lies between all the extremes of the model. Complex methods are cumbersome and will not entice widespread use within the industry, whilst methods that are too simplistic lack the necessary depth to provide meaningful guidance. Although cost is consistently shown as the main concern of construction clients, a more holistic method that is inclusive of both hard and soft aspects provides a balanced benefit assessment. The range of factors taken into account within the IMMPREST toolkit in order to deliver the balanced solution required are described in Table 2 below:

Table 2: Aspects of the IMMPREST benefit evaluation model.

Aspect	Explanation
Hard	*Monetary measures* – financial measures can be linked closely to profitability and compared directly to other financial measures. This allows comparison of different options or evaluation of trade-offs of benefit against dis-benefit, *Non-monetary* – quantitative measures used to measure factors with a numeric value, e.g. time, which are not dependent on the subjective opinion of the measurer,
Soft	*Numeric scoring systems* – subjective measures that are dependent on the measurers assessment, *Non-numeric assessments* – qualitative measures and descriptive scales of measurement,
Simple	Measures use concepts which are familiar and used regularly within the construction industry, and which can be explained easily to supply-chain partners,
Complex	Concepts and data rarely used and difficult to obtain for use in such measurement,

IMMPREST TOOLKIT

Developed as an antidote to the difficulties in evaluating OSP design alternatives, the research adopted a variety of methods to ensure rigor and validity in the research. Development of the Toolkit, through progressive conceptual designs, was aided by workshops involving construction professionals, contractors and clients. These focussed workshops were also used to test the Toolkit, refine the detailed content of the various tools and collect data from experts in industry. Further data was gathered through semi-structured interviews, case studies and questionnaire surveys. The Toolkit comprises of three distinct tools, an Introduction and Information Tool (Tool A), an Interactive Benefit Indicator Tool (Tool B), and a Benefit Measurement Tool (Tool C). Each tool introduces increasing levels of detail and specificity to the project and element being evaluated. The toolkit as a whole relies on the definition of the specific drivers and constraints for the project which in turn feed down into the benefit measurement used to consider design detail and the definition of these drivers and constraints derived from earlier work undertaken by CIRIA (2000). A headline set of five drivers and three constraints are used by the toolkit to guide the project decision making process, each with sub-divisions. These are shown in Table 3 below:

Table 3: Headline Drivers and Constraints for Design Decision

DRIVERS	
D.1. Cost	1.1 Ensuring project cost certainty
	1.2 Minimising non-construction costs (e.g. management, design, tendering costs etc)
	1.3 Minimising construction costs
	1.4 Minimising overall life cycle costs (e.g. more efficient maintenance)
D.2. Time	2.1 Ensuring project completion date is certain
	2.2 Minimising on site duration
	2.3 Minimising overall project duration
D.3. Quality	3.1 Achieving high quality (e.g. finishes, tolerances)
	3.2 Achieving predictability of quality
	3.3 Achieving performance predictability throughout the life cycle of the facility
D.4. Health & Safety	4.1 Reducing health & safety risks
D.5. Sustainability	5.1 Reducing environmental impact during construction (e.g. reduction of waste)
	5.2 Maximising environmental performance throughout the lifecycle
	5.3 Implementing Respect for People principles
CONSTRAINTS	
C.1.Site	1.1 Restricted site layout or space (e.g. storage areas)
	1.2 Multi-trade interfaces in restricted work areas
	1.3 Limited or very expensive available skilled on-site labour
	1.4 A problem transporting or delivering manufactured products to site
	1.5 Live working environment limits site operations
	1.6 Limitations to movement of pre-assembled units around site
	1.7 Site restrictions by external parties (e.g. neighbours noise restrictions)
C.2 Process	2.1 Short overall project time-scales (e.g. little time for testing or design)
	2.2 Unable to freeze design and specification early enough to suit pre-assembly
	2.3 Key decisions already made limit OSP approach
	2.4 Not possible for follow-up projects to use same processes and procedures
	2.5 No opportunity for product or component repeatability on this or future projects
C.3. Procurement	3.1 Project team members have no previous experience of OSP
	3.2 Obliged to work with a particular supply-chain
	3.3 Not willing to commit to single-point supplier
	3.4 Obliged to accept lowest cost rather than best value
	3.5 Limited capacity of supplier/s
	3.6 Limited expertise in off-site inspection
	3.7 Early construction/manufacturing expertise and advice unavailable
	3.8 Obliged to accept element-specific costing

Whilst the project drivers frequently seem to be the important factors in decision making, it is the constraints that have the greater potential to affect project outcomes. IMMPREST uses a penalty point scoring system to evaluate the suitability of OSP for the project by considering the project constraints. The effect of this is not only to guide the team during the project in hand but also to provide a learning vehicle for future projects. In effect, if OSP is to be used effectively, the constraining factors need to be addressed and disabled e.g. by ensuring the appropriate expertise is available, or the benefit may be reduced or may even become a detriment to the project

Consideration of the drivers and constraints within the Toolkit provides three major benefits. Firstly, the Toolkit promotes a holistic view of the issues that need consideration for a decision of whether or not to pursue an OSP option for a particular building element. Evaluation does not centre on the simple/hard measure of cost and time alone, but also takes the more complex, softer issues of quality, health, safety, and sustainability issues into account. Although the tools do not prevent users from concentrating only on cost and time, they are made aware of the different aspects of value. In addition, project constraints are introduced as aspects of value, such that their mitigation is viewed as being of added benefit to a project. Secondly, the Toolkit encourages a methodical approach to benefit evaluation in project decision-making that involves OSP products. Consistent methods of evaluation are needed, which ensure that all aspects of cost, and more significantly value, are represented fully within an evaluation. Conversely, consistent methods also highlight areas of benefit evaluation that have been omitted or poorly addressed, drawing the attention of the project team to possible shortcomings in the information provided for a decision. It further offers owners and facility stakeholders transparency of the entire decision-making process, adding support to value-based decisions, which are often more difficult for project teams to justify as they are usually not evaluated numerically.

CONCLUSION

This paper has argued that the decisions required to choose one method of construction over another involving OSP are too often based on cost rather than value. The evidence presented provides persuasive evidence of the deficiency within present benefit evaluation methods used to compare traditional and OSP solutions. It was shown that 'simple-hard' evaluation approaches predominate when OSP options are assessed in a construction context. The increasing complexity and value associated with OSP components dictates that a more robust, transparent and inclusive methodology is required for ensuring that a more precise assessment of the options is made. The factors that drive and/or constrain the selection of design options underpin the decision making process and provide a subtle guidance for changing the construction design culture to one that facilitates the realisation of the benefits that arise from the use of OSP by ensuring the appropriate conditions exist at the outset.

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