Benefit evaluation for off-site production in construction

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ABSTRACT

Evaluating to what extent a component or building system should be produced off-site is inadequate within the industry. The potential benefits of off-site production (OSP) are commonly cited when justifying an OSP approach, yet holistic and methodical assessments of the applicability and overall benefit of these solutions, to a particular project, have been found to be deficient. 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. Yet it is demonstrated that these issues are some of the most significant benefits of OSP. A series of case studies demonstrated that evaluation focus is almost solely on direct material and labour costs of components, without explicit regard for the wider cost or soft issue implications of OSP on a project. The paper argues that until evaluation is more holistic and value-based rather than cost-based, OSP uptake in construction will be slow. *(204 words)*

Keywords: benefits, evaluation, off-site production, pre-assembly, 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. The Australian construction industry has likewise more recently identified OSP as a key vision for improving the industry over the next decade (Hampson & Brandon, 2004).

The uptake of OSP in construction is limited however, 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 posited for the reluctance among clients and contractors to adopt OSP is that they have difficulty ascertaining the benefits that such an approach would add to a project (Pasquire & Gibb, 2002). 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.

The benefits of OSP are largely dependent on project-specific conditions, and the combination of building methods being used on a project. Decisions, regarding the use of OSP, are consequently unclear and complex. Direct comparison of components is not usually possible due to interdependencies between elements, trades and resources. These complexities make the derivation and use of holistic and

inclusive evaluation methods difficult. The unlimited combinations of components, site conditions and degrees of OSP do not permit the derivation of a comprehensive evaluation system; however sufficient common factors exist for a degree of valid comparative analysis.

A pilot study by Pasquire and Gibb (2002) 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. This paper extends the work of Pasquire and Gibb (2002), seeking to provide depth to their pilot study, which merely identified the problem. The current benefit evaluation paradigm of those deciding between traditional and OSP alternatives is described within the paper. Evidence is presented demonstrating that current evaluation methods for comparing traditional and off-site produced building solutions do not adequately account for all the main factors that affect cost, whilst also ignoring the wider benefits and disbenefits inherent within the different approaches. Current traditional models are largely ignorant of value and therefore cannot ‘record’ the benefits OSP can promote.

This paper investigates the proposition that current evaluation methods for OSP are cost and not value-based, and therefore cannot account for the recognized benefits of OSP. The consequence of this is that OSP invariably appears as an expensive alternative to traditional on-site options. The next section identifies the main benefits of OSP from previous research. The OSP evaluation methods of six cases are then analysed to demonstrate current emphasis in the industry. A discussion follows that elaborates on the implications of the discrepancy between current methods and the acknowledged benefits of OSP.

BENEFITS OF OFF-SITE PRODUCTION

The benefits attributed to OSP are numerous and well documented. Gibb and Isack (2003) conducted a large interview-based survey in which they determined construction clients' views on the benefits of OSP. Their findings showed that clients' perceived the benefits of OSP as being mainly time and quality based. Table 1 below summarises their findings in descending order of benefit.

Table 1: Clients' perceptions of the benefits of OSP (from Gibb & Isack, 2003).

Benefit	Description (* indicates high incidence)
Time	Less time on site – speed of construction *****
	Speed of delivery of product
	Less time spent on commissioning
	Guaranteed delivery, more certainty over the programme, reduced management time
Quality	Higher quality – on-site and from factory *
	Product tried and tested in factory
	Greater consistency – more reproducible
	More control of quality, consistent standards
Cost	Lower cost *****
	Lower preliminary costs
	Increased certainty, less risk
	Increases added value
	Lower overheads, less on-site damage, less wastage
Productivity	Includes less snagging
	More success at interfaces
	Less site disruption
	Reducing the use of wet trades
	Removing difficult operations off-site
	Products work first time
	Work continues on-site independent of off-site production
People	Fewer people on site
	People know how to use products
	Lack of skilled labour
	Production off-site is independent of local labour issues
Process	Programme driven centrally
	Simplifies construction process
	Allows systems to be measured

Further, interviewees of Gibb and Isack (2003) were asked to rank a list of key benefits from the initial interviews and literature, noting both the importance of the benefit and the likelihood of realising the benefit (Table 2).

Table 2: Rating of benefits from highest to lowest according to importance and likelihood [+ cost-related; # impact on cost] (from Gibb & Isack, 2003).

Benefit (from most highly rated to lowest rating)	Cost related
1. Minimises on-site operations	
2. Reduces congested work areas and multi-trade interfaces	
3. Minimises on-site duration	#
4. Improved health & safety by reduction and better control of site activities	
5. Produces high quality or very predictable quality finishes	
6. Minimises number of site personnel	
7. Benefits when only limited, or very expensive on-site labour	+
8. Enables existing business continuity	
9. Can cope with restricted site storage area	
10. Enables inspection and control off-site works	
11. Provides certainty of project cost outcomes	+
12. Provides certainty of project completion date	
13. Less environmental impact by reduction and better control of site activities	

The interviewees rated benefits in non-direct cost terms, such as minimisation of on-site operations; reduction of site congestion; reduction of on-site duration; improved health and safety etc. Direct cost benefits did not feature in these ranked lists (table 2), although identified within Table 1. These findings clearly demonstrate that, although OSP can offer direct cost benefit, the main benefits are from indirect cost savings and non-cost value-adding items.

Based on these findings, pure direct cost comparisons will favour traditional on-site operations that are costed on a rate-based system, with overheads, access, cranage, repairs and reworks hidden within preliminary costs. OSP costs are usually presented as all-inclusive amounts with a premium for off-site overheads. Having established

that the benefits of OSP are largely identified as non-cost items, the next section analyses several cases to ascertain the emphasis of current OSP evaluation methods.

CURRENT EVALUATION METHODS

Methods and cases

A simple inductive case study approach, underpinned by replication logic (Yin, 1994; and as used by Blismas, 2001) was used to consider the proposition that current evaluation practices are inadequate and therefore a major cause for the slow uptake of OSP into construction. Six cases were examined, in which project consultants and suppliers compared traditional and off-site for various building components. Data was provided from two cases currently being studied, three from previous undergraduate research and one from the pilot study of Pasquire and Gibb (2002). Data consisted of documents provided by sources that demonstrated a typical comparison between equivalent solutions of an element built on-site and off-site. It is appreciated that many other decisions would have been discussed and noted at meetings which were not necessarily documented. However, sufficient information resides within the documents to demonstrate the general tenor of such comparative exercises and to examine the proposition posed above.

Although the use of findings, or data collected by other researchers is fraught with methodological dangers, they nevertheless provide useful sources of research data. It is contended, with Kenly (1998), that construction management research does not make sufficient use of existing research for meta-analysis or even re-analysis. The case data provided by Walsh (2001) and Vaughan (2001), whilst supervised by the

authors, was ‘pre-analysis’ data as obtained directly from their data sources. This paper is therefore not a meta-analysis in the pure sense. It simply uses appropriate data collected in the same research field for alternative analysis.

Table 3 outlines the main features of the six cases individually. The cases have been labelled A to F to maintain anonymity. Ideally, a case study requires theoretical sampling (see Yin, 1994; Blismas, 2001) for cross-case comparison, although a more random case choice has been advocated by Simister (1994). This analysis adopts the latter approach, driven mainly by the readily available data, and the access to collaborating organisations. The cases nevertheless offered adequate variety across projects, elements and suppliers, to provide sufficient examination of the proposition.

Table 3: Outline of cases used for the comparative analysis.

Case	Element	Description of case data	Preparation	Data source	Comments
A	Multiple service distribution modules	Cost comparison within supplier organisation to justify their approach for installing pre-assembled multi-service distribution modules within an office block development	Different supplier's departments (one 'traditional', and other from 'manufacturing')	Swaffield, 1999	Supplier won tender on 'traditional' basis, however chose to undertake works off-site with pre-assembled units
B	Plant room system	Cost comparison exercise between traditional and pre-assembled boiler & cooling plant room procurement for a particular project	Cost consultant for chain of stores, module costs provided by manufacturer	Vaughan, 2001	Used historical data of previous project for comparison with a view to implementing on a new development
C	Skid-mounted boiler	Cost exercise between typical traditional installation and an off-the-shelf standard boiler system, for marketing purposes	Supplier of pre-assembled mechanical services	Direct data	Standard solutions marketed by the manufacturers as saving time over traditional installation
D	Chilled Beam Supply	Cost and benefit evaluation of various options for chilled beam supply into an airport terminal produced to satisfy client requirements	Partnered supplier of ductwork and chill-beams	Direct data	Framework agreement with the client dictated that justification was required for chosen solutions
E	Toilet pods (Residential)	Cost comparison of traditional bathroom construction versus pre-assembled bathroom pods produced for bidding using tenders from other suppliers	Cost consultant and suppliers of the main contractor	Walsh, 2001	The high number of options within this development decreased the benefits of the economies of scale
F	Toilet pods (Office)	Cost comparison of traditional bathroom construction versus pre-assembled bathroom pods produced for bidding using tenders from other suppliers	Cost consultant and suppliers of the main contractor	Walsh, 2001	Highly repetitive with low variations and therefore ideally suited to pre-assembly

Analysis

The data, from each individual case, was distilled into Table 4 to highlight the emphasis of each of these current benefit evaluation methods. The 16 column headers that formed the categories across which each case was analysed, were obtained through assimilation of factors indicated in BSRIA reports (1999), the CIRIA Standardisation and Pre-assembly Toolkit (2000), the Pasquire and Gibb (2002) pilot study, and interviews with practitioners in industry. The 'traditional' and 'pre-assembly' evaluation of each case was tested against each of the 16 factors or categories. This was to determine the extent and depth of the documented evaluation process, and to further highlight where the emphasis lay. Symbols were used to indicate whether these factors were explicitly or implicitly included, incorporated in preliminaries or totally excluded from these comparisons.

Table 4: Analysis and cross-case comparison.

		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*

The most striking observation was that most cases did not have any formal procedures for making detailed and suitable comparisons between options. Of the various collaborating organisations, only those involved with a highly progressive client were able to produce any documentation justifying their choice of installation methods. In all cases, other than case D, information regarding project decisions were diffused among several disparate documents, or lost entirely through unrecorded conversations. The issues are therefore very difficult to retrieve and assimilate into a holistic representation of the decision process. The assessments are based on documents that directly refer to the element being compared.

Case D clearly incorporated a more holistic view of both cost and value within the comparative assessment exercise presented. Case C included broader cost items that are usually included with preliminaries, in order to give a much more inclusive and realistic cost of each option, yet failed to elaborate on other issues such as health, safety and sustainability. The remaining four cases were clearly focussed on the simple cost aspects of labour and material costs, with further implied inclusions. Extracting the totals from Table 4 further, depicted in Figure 1, reveals the emphasis of the cases more clearly.

< FIGURE 1 HERE >

The cross-case analysis of categories in Figure 1 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 due to the increased volumes being moved and the associated increase in cost and logistical effort. However, apart from these three explicitly included cost items, all other issues are evident in less than half the cases of the study. 'Softer' issues such as health, safety, quality, human and environmental factors are almost totally excluded. Important cost items relating to quality and rectification of works are generally implied within the totals, being accounted for in the 'claims' that will be negotiated at the end of the project. The emphasis of the cases is clearly within simple monetary measures that can be easily grasped and calculated.

EMPHASIS OF CURRENT METHODS

In order to assist the analysis of benefit measurement methods further, a categorisation model was developed. The model is presented graphically in Figure 2. The categorisation model comprises of two aspects of measurability, identified as hard-soft and simple-complex, explained in Table 5 (from Pasquire *et al.*, 2004). All methods employed within the construction industry to evaluate various building approaches may be categorised into one of the quadrants of the model. 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.

Table 5: Aspects of the 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.

(Source: Pasquire *et al.*, 2004)

Taking the analysis of Table 4 above, each case is placed within the model depicted in Figure 2. All cases, other than D, quite obviously reside within the 'Simple-Hard' quadrant of the model – strongly emphasising the behaviour of the industry. Case D described the decision process in a graphic decision flowchart, which was accompanied by cost data, advantages and constraints for each of the options being considered. This document however, was produced at the request of an experienced and progressive construction client organisation, and may therefore indicate that clients are the primary drivers for change in the way the construction industry views value.

< FIGURE 2 HERE >

The problem 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. In addition, 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.

An ideal solution would be 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 would be required to provide a balanced benefit assessment. In addition, the cost aspects need to be more thoroughly addressed to cover all product, project and whole-life costs.

IMPLICATIONS

A comparison of the primary benefits of OSP and the focus of current OSP evaluation systems clearly shows a significant discrepancy in emphasis. OSP benefits are not directly monetary, whilst current systems are almost entirely direct-cost based. With such methods dominating the industry, OSP will invariably appear as an expensive option. The implications of this discrepancy are further discussed under the following headings; Value, Knowledge and Processes.

Value

There continues to be a climate, within construction, of benefit evaluation based almost solely on cost. Non-monetary benefits and disbenefits of the construction process are merely alluded to, or disregarded. The investigation found that all cases had significantly differing methods of evaluation. All, but one, were purely cost-based in their comparisons. These five cases nevertheless still omitted many significant costs implied within other figures, such as preliminaries. Yet it is contended that the cost implications of a traditional approach over an OSP alternative significantly alter the preliminary figures. Temporary works or site facilities may be greatly affected by the building methods employed. Apart from the poor build-up of cost figures, only one of these cases regarded any of the wider, softer issues involved with considering the benefits or value of OSP. A more holistic and thorough value-based comparative system is required by the industry to ascertain the true benefits of OSP for particular project settings.

Using such a rate-based system and taking an elemental view by considering the building element in isolation, will often make off-site produced units appear more expensive, as concluded by Pasquire and Gibb (2002). For example, the overheads and set-up costs of the factory are covered within OSP unit costs, whereas the equivalent costs for traditional site-based approaches are often ‘lost’ in principal contractors’ preliminaries. Furthermore, in line with a free-market economy, many manufacturers and suppliers seek the maximum price that the market will sustain. Therefore prices quoted may not reflect the actual costs, and therefore hinder sensible comparison with conventional construction (Gibb, 2001).

A wider account of value-based measures including quality, health, safety, sustainability, and logistics is suggested as the means of broadening the comparative exercise from the one-dimensional cost basis to a multi-dimensional value-based system. The cases clearly view value as solely constituted of cost items, which perpetuates non-value and inefficient means of ascertaining optimal building solutions, and consequently disregard the potential benefits of OSP.

Knowledge

The shortcomings of the cases examined are further demonstrated by the general lack of particular documentation regarding OSP decisions. All cases, except case D, lacked a set of documents or information that recorded the decision and the process of deciding on whether to use OSP on a project. This leaves an organisation with no basis for measuring performance or capturing project knowledge, thus reducing its scope for improvement. Without structured formats for capturing project data, knowledge is lost within and between projects. Records of a decision are usually scattered among different team members and do not reliably encapsulate all the main aspects of a decision. Databases of historical data cannot be constructed, rendering organisations stagnant rather than growing and evolving entities.

Further, without the provision of a framework for the methodical assessment of OSP on a project, the opportunity for benchmarking and performance measurement is lost. Measures of several different aspects of value offer the basis for performance measures and indices. Project teams are then able to track their, and the element's performance throughout the project life by referring to the foundational document

that recorded the expected value to be gained. The auditability of such a framework also allows teams to trace their decisions and ascertain where realised value may have departed from expected value. The potential for teams and organisations to learn are rooted in systems that are able to explicitly capture reasons for decisions usually made implicitly by team members. They provide a focus around which innovations are developed and value is achieved for the benefit of all parties.

Processes

The cases examined also indicate that consideration of OSP as a building option appears to be retrospective. The cases imply that the building and its components were designed in a 'traditional' manner, with OSP being considered as a late alternative. The cross-case comparisons were therefore based on existing rate-based costs, thus forcing the OSP alternative into a direct cost comparison. Case D was the exception, demonstrating a pre-design comparative exercise, which enabled more combinations to be explored in a holistic and balanced manner.

CIRIA (2000) asserted that OSP benefit is best realised when OSP is considered in the early design stages and not as an alternative to a completed 'traditional' design. This suggests that the implications for OSP are compounded, as not only are the benefits not accounted for, but a lack of appreciation of the processes involved for OSP may result in those purported benefits not being realised. Indeed success in OSP requires changes to the design, evaluation and construction processes. Case D suggests that this may only be achieved through the efforts of progressive clients.

CONCLUSION

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.

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. OSP is hindered by the industry's perception that value is best ascertained using traditional rate-based measuring systems. Softer issues such as health and safety, sustainability, and effects on management and process are either implicit or disregarded within their evaluations. The cases provide persuasive evidence of the deficiency within present benefit evaluation methods used to compare traditional and OSP solutions. Using six cases, it has been 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 discrepancy between current evaluation systems and the identified benefits of OSP provide a convincing argument as to why OSP is not widely adopted, and supports the findings of the Pasquire and Gibb (2002) pilot study. The perceived high cost of OSP solutions, unless balanced by an understanding of value, will result in a continued reluctance by the industry to more fully embrace the approach. OSP uptake in the industry will not improve unless rigorous methods for OSP benefit analysis are developed that take account of site-specific complexities.

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FIGURES

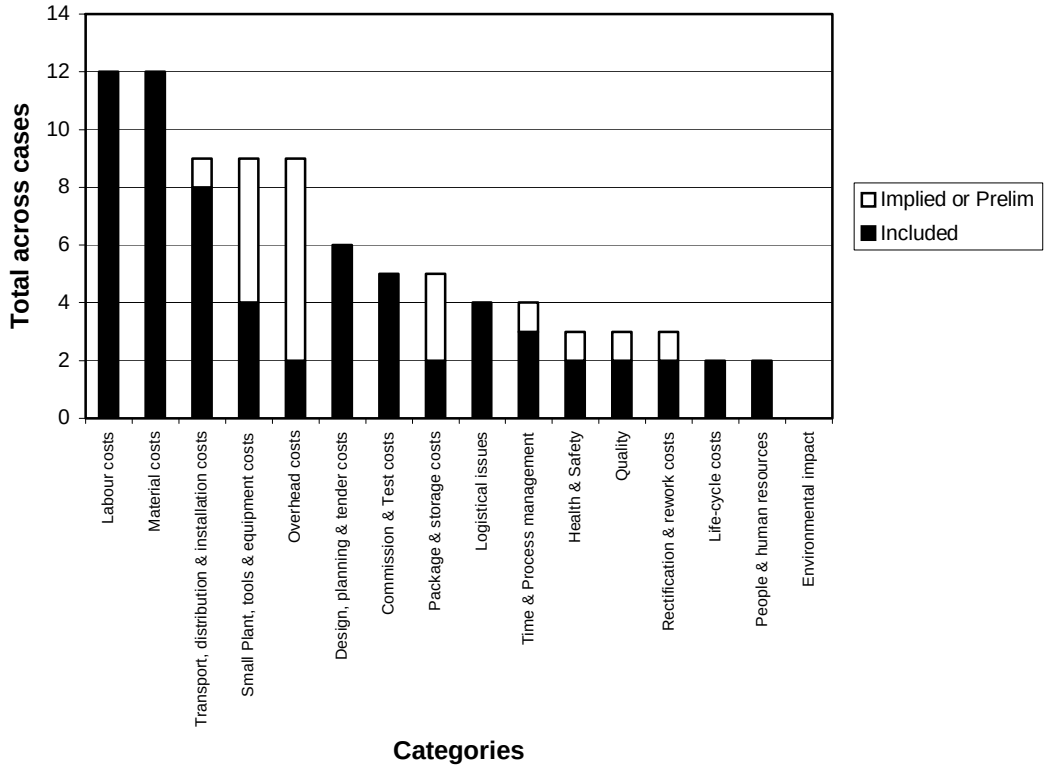

Figure 1: Cross-case analysis of categories in Table 4.

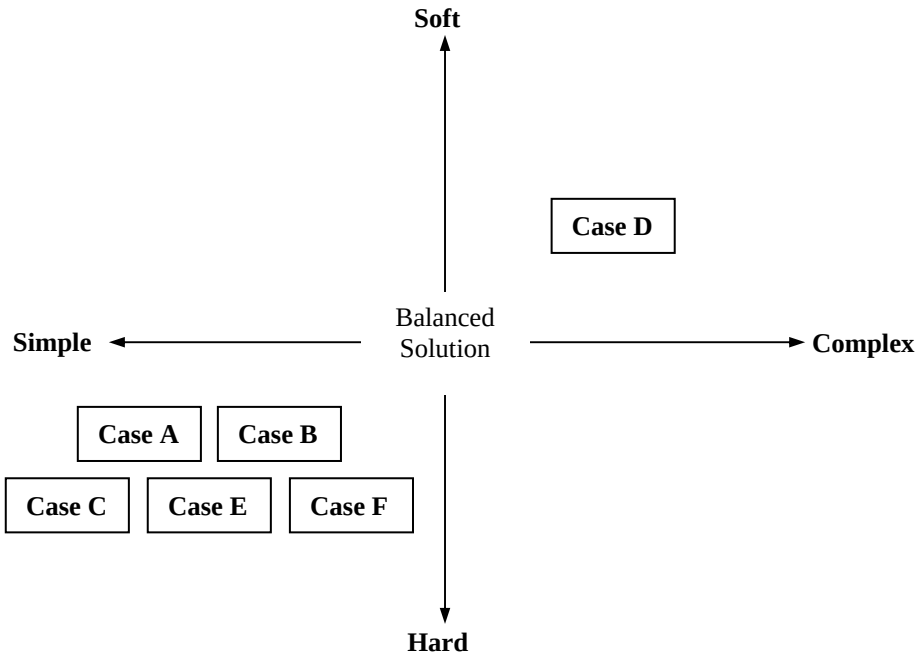

Figure 2: Categorisation of several different evaluation methods utilised to assess the benefits of OSP over traditional construction approaches.

ENDNOTES

[1] Offsite production can be defined as the completion of substantial parts of 'construction' works prior to their installation on-site. 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).