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CONSIDERATIONS FOR ASSESSING THE BENEFITS OF STANDARDISATION AND PRE-ASSEMBLY IN CONSTRUCTION

(THE FINDINGS OF A PILOT STUDY)


Running Title: Considerations for Assessing S&P Benefit

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Considerations for Assessing the Benefits of Standardisation and Pre-Assembly in Construction (The findings of a pilot study)

Abstract

This paper describes the findings of a six-month, pilot study funded by the EPSRC under the Meeting the Client's Needs through Standardisation (MCNS) LINK programme. The research explored the needs and opportunities for identifying and evaluating the benefit of standardisation and pre-assembly to the construction industry. The pilot study focused principally on pre-assembly in the Mechanical sector, drawing data from both manufacturing and construction processes. A principal aim of the study was to take a snapshot of how construction clients could derive greater benefit from pre-assembly. This was much broader in concept than the case studies within the Mechanical sector but nonetheless sufficiently related to maintain cohesion in the research. The principal conclusions of the pilot study were that:

1. No existing metrics were currently available to evaluate the benefits identified; and
2. Without these metrics comparative design decisions were being made based on capital cost or intuition alone.

Key Words: Standardisation; Pre-assembly; Benefit Evaluation; Construction; Management;

INTRODUCTION

Standardisation and Pre-Assembly (S&P) have been talking points in construction for many years. However, over the last decade interest in their effective implementation has increased considerably. Numerous studies have been completed (for example White 1965, Russell 1981, Finnimore 1989) and S&P were identified as part of the solution to the problems raised by Egan (1998). CIRIA have produced several milestone publications, namely: Snapshot (1997), S&P adding value (1999) and Clients’ Guide and Tool Kit to S&P (2001), BSRIA
(1998) have produced guidance for the Building Services sector and the CIOB (Neale et al 1993). The CBPP (Construction Best Practice Program) include S&P in their recommendations for industry best practice.

So far, the work has concentrated on strategic process issues. The latest CIRIA tool kit (2001) starts to provide tools to enable project teams to identify opportunities and manage the implementation of S&P as well as recognising the need to measure the extent of S&P success.

Notwithstanding the above work, which has clearly brought S&P back into focus, an effective benefit value model has so far eluded the various researchers. This means that most of the decisions made are still based on anecdotal evidence rather than rigorous data as there are no formal measurement procedures or strategies available. The research described by this paper challenges the perceptions about the advantages and disadvantages attributed to S&P by the studies listed above, and investigates the extent to which these are and could be measured. It goes on to define and develop a prototype model (Figure 1), providing a framework within which to collect and analyse data. The framework was scrutinised by industry through both an industrial research steering committee and an industrial workshop. This latter was particularly useful in developing the research deliverables, enabling the team to concentrate on those aspects that would be useful to industry.

Concepts

Standardisation is a far-reaching concept, which has been well discussed. For the purposes of this research it was taken to include the extensive use of components, methods or processes with regularity, repetition and a successful history. Standardisation can exist across an industry sector (e.g. Standard Methods of Measurement RICS, ICE; Standard Forms of Contract; standard brick sizes etc), inter/national (e.g. British Standard 5750, ISO 9000) or may be specific to a client, supplier or project (e.g. internal processes, corporate image etc).

Pre-assembly was taken to be the organisation and completion of a substantial portion of final assembly work before installation into its final position. Pre-assembly was defined by Neale et al (1993) as:
Component sub-assemblies: e.g. door and window sets,
Non-volumetric pre-assembly: e.g. frame sections, cladding panels
Volumetric pre-assembly: e.g. bathroom pods, boiler houses
Modular Building: e.g. room modules, whole building systems such as used by Macdonald's

Pre-assembly was frequently (but not exclusively) found to take place off-site in factories (off-site manufacturing) and although often comprising standard components and procedures did not necessarily produce standard units. Indeed, many of the manufactured mechanical units observed in the case studies were non-standard and the technique was considered to be a more satisfactory method for complex designs due to constraints such as access to final installed position, space within the assembly, intricate connections etc. An example of combined off- and on-site pre-assembly was found for a gantry at Heathrow (BAA) where an amount of pre-assembly was undertaken in the factory and the final assembly completed on the ground on-site before lifting into position. This minimised the disruption to the taxiway below thus keeping the airport operational.

**Potential benefits of standardisation and pre-assembly**

These have been considered within the studies named above, summarised after the style of Gibb (1999) and tested during the interviews are listed on Table 1.

**Barriers to standardisation and pre-assembly**

Despite the drive of Government (Latham 1994, Egan 1998) and other influential bodies to increase the use of S&P, the interviews suggested the construction industry slow to adopt S&P. This suggests there are barriers that need to be addressed before the benefits identified can be fully realised. These barriers are identified by CIRIA (1999) as:

- Failure to consider all relevant costs
- Failure to get full project team commitment
- Failure to measure benefits
- Failure to stimulate innovation
- Failure to involve manufacturers and suppliers early
- Failure to make key decisions at optimum time
- Failure to apply S&P within an overall business or project strategy
- Failure to change process from construction to manufacturing

*How to achieve & optimise the benefits:*

CIRIA, in its Client's Guide and Tool Kit (2001), identify the following three steps to achieving and optimising benefit from S&P:

1. Step 1 Use standard processes
2. Step 2 Consider standard components
3. Step 3 Consider pre-assembly

It is proposed this process will enable the design team to identify the opportunities for standardisation and pre-assembly, leading in turn to maximising the benefit from the use of S&P. But, it is contended this benefit will only be fully realised once the success of the project can be adequately measured. Misconceptions about and mismanagement of the S&P process can lead to inefficiencies and additional cost as was discovered during the research case study. The converse is also true, without effective, scientifically based information on which to make decision, S&P or parts thereof may be included in the design solution when they are not appropriate. Any measurement system must facilitate the “correct” decision for the circumstances and not lead to the inclusion of S&P as a matter of course.

**RESEARCH METHOD**

The perception about advantages and disadvantages was tested through forty-five structured interviews within personnel from companies across the supply chain. The interview structure was based closely on that used by CIRIA (1999) to test Client opinion. This structure was amended to reflect the focus on the Mechanical sector and the broader interviewee base. The findings from the structured interviews were validated during the workshop (see below). Existing cost data and factors influencing cost were collected from project and company data, observation
and case study within companies specialising in pre-assembly and component manufacture. The research progress was monitored by an industrial steering committee.

A prototype benefit evaluation model was developed through a process of iteration between the research team and personnel from the companies on the steering committee. Additional organisations were co-opted as necessary. The model used basic construction process logic as a foundation and it was tested in theory by one of the steering committee members.

The research methods used were supplemented by an IT supported workshop. This was found to be a powerful method for both collecting and validating large quantities of data in a short time span. Twenty-five attendees at the one-day workshop each had a linked laptop into which comments, questions and discussion could be typed while presentations and verbal discussions were taking place in the room. The attendees were interested parties from industry and then workshop used to validate the research findings and identify a way forward.

INTERVIEW FINDINGS

The structured interviews tested the earlier work of CIRIA (1999) and are summarised as:

Interviewees Comments on Perceived S&P Disadvantages
The disadvantages attributed to standardisation were dismissed out-of-hand. Several instances were given of standardised components being assembled in new and interesting ways, thus demolishing all argument as to dullness, lack of flexibility, intelligence or responsiveness.

The disadvantages associated with pre-assembly were claimed to be nothing more than a list of things to avoid. The interviewees generally felt these disadvantages were avoided in practice. However, there was a noticeable uncertainty as to whether or not pre-assembly attracted an overall cost increase. This was attributed to an uncertainty over the cost of setting up workshop facilities and the fact that for
most, pre-assembly was a recent innovation and costs were not yet distributed over enough projects to be realistically component-assessed. One specialist explained that circumstances of workload and availability of site-oriented operatives were also considerations when deciding whether or not to pre-assemble.

**Interviewees Comments on Perceived S&P Advantages**

In opposition to the CIRIA (1999) findings, the interviewees for this research generally believed that standardisation did not lead to a reduction in on-site training.

On a more specific note, pre-assembly of mechanical services did not lead to earlier on-site weatherproofing (except in the special case of pre-assembled boiler rooms and the like). Linked to this, the interviewees also felt it did not necessarily lead to faster overall completion time, because, although the mechanical work may be completed earlier, if it is not on the critical path there is no overall gain.

The interviewees did display whole-hearted enthusiasm for standardisation and pre-assembly whenever the opportunity arose, and for the underlying spin-offs of better planning, better control, better quality, the innovative environment and the feel-good factor that came from the discipline involved in implementation of standardisation and pre-assembly.

The interviewees all recognised the benefit available for their organisation through the adoption of S&P. However, they confirmed that S&P will only be embraced if all parties receive benefit. Therefore any benefit must be shared and not wholly retained or there is no incentive to change from traditional methods.

**Measurement**

None of the interviewees made any formal exercise to measure the advantages and disadvantages of standardisation and pre-assembly.

**Contractual arrangements**

Contractual arrangements were thought to have a substantial effect upon the degree to which standardisation and pre-assembly were feasible. Typical arrangements
found by the survey were two-phase tendering combined with value management, term contracts, and partnering in one form or another. In such arrangements, early consideration can be given to standardisation and pre-assembly and their impact on all aspects of total project design.

It was claimed that this close working of the whole team at an early stage reduced error and the resulting conflict, improved efficiency (which includes reducing cost and/or increasing quality), and that such is not usual in a traditional setting. Although when challenged, the participants admitted these claims were intuitive rather than based on formal measurement.

CASE STUDY FINDINGS

The principal objective of the case studies was to examine existing company and project cost data to identify the factors that caused and influenced cost and thus contributed to the methods for measuring benefit.

Existing data

The study confirmed that data recorded and used within the participating companies comprised the traditional cost focused accounting data such as:

- Resource cost;
- Overhead;
- Turnover;
- Profit;
- Fees & charges;
- Project enabling works etc.

This data accurately recorded cost incurred and was used to set prices, charge and monitor income but was by no means the only information required if full cost implications were to be understood and subsequently measured. There were many factors found to be affecting cost that were not adequately recorded (if at all) and not in monetary terms. These included:

- Lead in Times: time required from order to delivery, possible the most straightforward factor;
• Flexibility to Change: tolerance and impact of change orders at varying times in the process;
• Quality & Performance: highly complex and subjective, includes technical specification, aesthetics, client perception, predictability;
• Management: includes assessment of level of supervision required for installation,
• Life costs: adds cost-in-use and refurbishment costs to capital costs to give life comparison;
• Design costs: consultant, manufacturer and installers may all contribute to the design process, should consider the benefits of rationalisation and optimisation;
• Integration: cost of not integrating/co-ordination often expressed as claims for additional cost or non-recoverable cost; and
• Environmental: very broad area including waste, recycling; energy (both embodied and in use), health and safety in production, installation and use;

However, this data was insufficient to facilitate the evaluation of benefit accrued specifically as a result of S&P. This was a partially as a result of insufficient classification of data and partially as a result of shortfalls in information generally. As benefit was not well measured within specific companies, it was difficult for them to justify or propose its use in the design. The shortfalls in information were associated with the evaluation of following issues:

1. Indicating and monitoring performance (KPI's)
2. Factors contributing to success (Critical Success Factors/CSF's)
3. Manufacturing and installation process.
4. Impact of differing relationships

Although it was found that data relating to these four issues were not collected, there was a growing recognition within the organisations participating in the research that these issues were important to business success and needed to be addressed. To start with, a relationship does exist between the data currently collected and that required to fully evaluate benefit. Specifically some existing data relates to organisational issues (lead-in times, management) and some data relates
to design (flexibility to change, reworking) and these can be manipulated to in order to address the issues listed.

**Factors Within The Processes That Cause Additional Costs**

Analysis of the interviews, observations and case study information led to the identification of the following apparent inefficiencies within the processes, which could result in unnecessary additional costs:

- The failure of the main contractor's management team to understand the method statement or account for the implications of the pre-assembled installation method. Examples observed included abandonment of the ceiling module installation because the floor above was being concreted at the same time; work areas not ready to be handed over for the specialist contractor to install modules; unsuitable scaffolding provided, requiring adaptation before module installation could commence; and crane availability not ensured.

- Construction operatives' failure to recognise the cost significance of the pre-assembled modules, and exercise additional care in handling materials and finished pre-assembled modules. Damage of a pre-assembled component on site or in transit has greater cost, time and process implications than damage of traditional construction materials.

- Design/production/installation learning curve. The case study project experienced problems with the condensate pipework (which is laid to a fall) becoming damaged in transit, presumably due to lack of care by operatives. The management decided to re-design future modules, removing the condensate pipework to prevent damage. The process was then re-arranged to allow for the condensate to be installed traditionally. This experience resulted in additional design work, abortive manufacture work, and additional installation time; all incurring additional costs.
Management culture and time required to adapt to a new business approach. The staff involved with the case study project had experience of working in the traditional confrontational environment of construction projects, with no evidence of special training in the new approach. The researcher observed instances of lack of trust and teamwork, and a general commercial secrecy and unwillingness to share information with colleagues from the same company, but based in a different operation - namely between the pre-assembly organisation, regional office and the site. There appeared to be some resentment among the regional office staff that they did not have access to the actual cost information from the pre-assembly organisation.

Interfaces between new and traditional processes. Cost reporting from the case study site and regional office followed a traditional system, with the pre-assembly organisation being treated effectively as a subcontractor, expected to provide cost breakdowns, agree rates, etc. This was observed to be a primary cause of the lack of trust and secrecy described above.

Continuity of work for subcontractors. The pre-assembly organisation was effectively "an extension of the site", and hence could employ their own specialist firms where required, (e.g. lagging). However, but work continuity for any subcontractors was dependent on production of modules, testing, painting, and the delivery schedule for site. All must be carefully managed or the specialist firms would charge additional costs due to disruptive working. Even though some of the disruptions could be the fault of the site or regional office, it would be the pre-assembly organisation that was charged the additional costs, as it was their specialist sub-contractor.

Conflicts between trades. Some of the traditional conflicts between different trades working on the M&E installation could still occur, but be removed off-site to the pre-assembly organisation. Although the directly employed labour force is multi-skilled and well organised, conflicts could still arise with the specialist subcontractor firms employed to work at the pre-assembly
organisation for specific tasks, (see continuity of work for subcontractors above).

- The timing of key decisions - "the window of opportunity". This applies to the early stage decisions as to whether to use standardised products or processes and whether to pre-assemble, but also to when changes to the design of pre-assembled modules can be made during the process. For example, the late timing of the decision to remove the condensate pipework from the multi-service ceiling modules, (as described above), resulted in substantial abortive works.

- Failure of processes to capture knowledge. Construction organisations tend to rely on key people who hold the knowledge. An unfortunate consequence of this could be that process improvements might not be realised due to the reluctance of experienced people to embrace new ideas and methods of working. Resistance from within could frustrate processes, leading to delays, disruption, inefficiencies, poor working practices, and additional costs.

**MANAGEMENT OF EVALUATIVE DATA**

There are two main problems associated with holding cost data. Firstly, costs go out of date rapidly and need constant up dating. Secondly, the quantity of data required is large giving rise to difficulties in finding and manipulating the relevant information without sophisticated classification and software systems. The occurrence of company specific databases and associated classification systems militate against standardisation of management processes and an industry wide approach is to be preferred.

If therefore, large, company specific data bases are to be avoided, the most crucial factors in the successful evaluation of benefit will be what data is to be used, where it is held and how it is accessed. The logical solution is for the pertinent information to be held and supplied by the appropriate organisation/s within the supply chain and for the position of the data within the supply chain to be mapped.
The obvious vehicle for accessing this data is the Web and much work is being undertaken to facilitate this type of data access (e.g. A-Site supported by CBPP and lead by Sir John Egan). This method for managing evaluative data will have the additional benefit of pulling the supply chain together and can easily be set up on a project by project basis or even more appropriately for the increasingly implemented longer term, partnering type relationships advocated by Latham (1994).

PROPOSED BENEFIT EVALUATION METHODOLOGY

A literature search failed to reveal suitable existing performance measurement systems, this position is supported by Neely et al (1995). The topic of measuring performance is at the forefront of current development and headline performance indicators have been implemented by CBPP (KPI Working Group 2000). The first step in the proposed methodology was to produce a framework within which to model and evaluate the benefit associated with S&P. This is illustrated in Figure 1.

It was proposed an evaluation study may be undertaken at any stage in the project life cycle and by any member of the demand or supply side. One of the main evaluation methods is the use of matrices for decision support for example, at strategic project phase, the use of pre-assembled services modules is given in Table 2. Scoring and weighting techniques are widely used in value engineering (Dell’Isola 1997) and much of the eventual data interrogation techniques required to implement the final benefit evaluation model will have their roots in the function analysis of VE (Park 1998) and the value theory of Lean (value, value stream, flow, pull and perfection) (Womack and Jones 1996). These facilitate the critical appraisal of Client requirement leading to the “correct” decision referred to earlier. If aspects of S&P are not appropriate, then the model must be able to indicate this as well as pointing to benefit.

At pre-construction/installation phase, component or product evaluations can be undertaken which identify the aspects of benefit that add value as a result of:
1. improving efficiency (measured as a direct cost impact);
2. increasing effectiveness (less easy to quantify, affects productivity) or
3. enhancing performance (not measurable in cost terms, identified as a "happiness/feel good" factor).

An example of the factors that may be considered and their value measurement unit is given in Table 3.

An example of the comparison of direct cost factors is given in Table 4 and a method utilising scoring in a matrix to prioritise factors that can not be costed directly is given in Table 5.

**Validation of the Research**

The findings and the evaluation framework and methodology were discussed and refined by the industrial steering committee and tested via an interactive one-day workshop held at Loughborough University. A large quantity of data was collected at this workshop as a result of using linked laptops into which delegates could both answer direct questions displayed on the screen and type in comments and observations on either the presentations being made or in response the exercises they were undertaking. An additional benefit of this method of collecting data is that the delegates could pursue discussions on their screens as presentations were being made. This mainly took the form of a delegate asking if anyone had any experience of something just said in a presentation and seeing on their screen several examples recorded immediately by other delegates; or clarification of a technical point, definition or other aspect. The workshop was used to confirm the findings of the survey interviews and case study and to refine the proposed methods for evaluating benefit and model concept.

The outcome of the workshop and steering group discussion was the preparation and subsequent award of a major grant from the EPSRC/DETR LINK funded MCNS programme and the expansion of the research into a 3 year project entitled IMMPREST (Integrated Model for Measurement of PRE-assembly and STandardisation benefit across the construction supply chain). This research project is scheduled to be completed in September 2003 and can be accessed until that date through the web site at www.immprest.com.
FINDINGS AND CONCLUSIONS

The principal findings of the pilot study were:

1. Standardisation and pre-assembly can contribute to the improved performance within the construction industry. It can improve the health & safety environment, add value for money, offer increased profitability, productivity, predictability and reduce cost, time and defects.
2. The factors affecting the success of S&P are myriad and will vary in their impact from project to project in the same way the individual project factors vary one from another.
3. For S&P to be widely adopted by the construction industry, benefit must be easily identifiable and accessible to all parties involved.
4. Evaluation of the benefit of S&P must allow full consideration of the objectives of both the Client and other stakeholders in the project.
5. S&P benefit may be measured in direct cost terms but this will not reveal the true value of S&P to the project and the stakeholders. As a result pure cost comparison to traditional construction methods will often place S&P option at a disadvantage.
6. Traditional contracting and construction management methods often prevent the full benefit of using S&P being realised.

These findings gave rise to the overall conclusions that
1. No existing performance measurement systems were available to evaluate the benefits identified; and
2. Without these systems comparative design decisions were often being made on capital cost or intuitive basis.
3. Benefit could not be verified without an effective measurement system.

The importance of a measurement system to sound decision making can not be over-emphasised, according to Lord Kelvin (quoted by Neely et al 1995) “When you can measure what you are speaking about, and express it in numbers, you know something about it…(otherwise) your knowledge is of a meagre and
unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in thought advanced to the stage of science.”

References

1. BSRIA (1999) Prefabrication and Pre-assembly - applying the techniques to building engineering services, Building Services Research Information Association, ACT 1/99
FIGURE 1: PROTOTYPE BENEFIT EVALUATION FRAMEWORK
1. For standardised processes the benefits include:

<table>
<thead>
<tr>
<th>Benefits</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rationalised interfaces</td>
<td>Minimised disruption</td>
</tr>
<tr>
<td>More predictable on-site activities</td>
<td>Better able to cope with congested sites</td>
</tr>
<tr>
<td>Increased productivity through familiarisation</td>
<td>Statistical reduction in H&amp;S and environmental hazards</td>
</tr>
<tr>
<td>Less waste, noise, dust etc</td>
<td></td>
</tr>
</tbody>
</table>

2. For standardised components the benefits are:

<table>
<thead>
<tr>
<th>Benefits</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tried and tested track record</td>
<td>Available replacement parts</td>
</tr>
<tr>
<td>Increased productivity through familiarisation both in design and on-site</td>
<td>Greater certainty of completion date</td>
</tr>
<tr>
<td>Reduction of waste</td>
<td>Minimised overall project time</td>
</tr>
<tr>
<td>Use of the same components on follow-on projects</td>
<td></td>
</tr>
</tbody>
</table>

3. For pre-assembly generally the benefits are:

<table>
<thead>
<tr>
<th>Benefits</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rationalised interfaces and improve tolerances</td>
<td>Reduction in H&amp;S and environmental hazards</td>
</tr>
<tr>
<td>Improved quality control</td>
<td>Minimised disruption</td>
</tr>
</tbody>
</table>

4. For off-site assembly/manufacturing (in addition to pre-assembly generally) the benefits are:

<table>
<thead>
<tr>
<th>Benefits</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimised on-site operations, personnel &amp; duration</td>
<td>Multi-skilled factory work force</td>
</tr>
<tr>
<td>Less waste, noise, dust etc</td>
<td>Less on-site activities</td>
</tr>
<tr>
<td>Decongests site</td>
<td>Off-site inspection</td>
</tr>
</tbody>
</table>

**Table 1: List of Benefits**
### TABLE 2: Benefit Evaluation Matrix for Use at Strategic Level:

1) Pre-assembled services modules incorporating major framed components: cost reduction £71,250; programme reduction 33 days

<table>
<thead>
<tr>
<th>Factors</th>
<th>Considerations</th>
<th>Data Req'd</th>
<th>Data Sources</th>
<th>Barriers</th>
<th>Add Value</th>
<th>Days</th>
<th>Cost Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>Less on site time</td>
<td>Certainty of Delivery</td>
<td>Lead in times</td>
<td>Manufacture r</td>
<td>Delays on other elements</td>
<td>-30</td>
<td>-0.75%</td>
</tr>
<tr>
<td>Quality</td>
<td>Pre-tested Zero defects</td>
<td>Careful site handling</td>
<td>Test certificates</td>
<td>Manufacture r</td>
<td>D</td>
<td>-1</td>
<td>-0.01%</td>
</tr>
<tr>
<td>Operational</td>
<td>Fewer operations</td>
<td>Standard interfaces</td>
<td>Design</td>
<td>Manufacture r &amp; Engineer</td>
<td>P</td>
<td>-2</td>
<td>-0.02%</td>
</tr>
<tr>
<td>Cost</td>
<td>Higher first cost</td>
<td>Increasing</td>
<td>Manufacturing &amp; Installer</td>
<td>None</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>People</td>
<td>Multi-skilling off site Fewer on site</td>
<td>Reduced on site storage details</td>
<td>Manufacturing r</td>
<td>Premature/late delivery</td>
<td>0</td>
<td>-0.01%</td>
<td></td>
</tr>
</tbody>
</table>

Outline description of project strategy e.g. 5 storey steel framed office block XXm² plan area

"Traditional" construction: Budget cost: £9,500,000 Contract period: 537 days

Pull down menus list what data required & where held. Includes URL/Website links.

Barriers identified as pull down lists of things to avoid or look out for.
**TABLE 3 : Items to be Costed For Component Comparison (more than one measurement unit may be appropriate)**

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Value</th>
<th>Item</th>
<th>Unit</th>
<th>Value</th>
<th>Item</th>
<th>Unit</th>
<th>Value</th>
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<th>Value</th>
<th>Item</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>££</td>
<td></td>
<td>Supervision</td>
<td>££</td>
<td></td>
<td>Energy</td>
<td>KJ</td>
<td></td>
<td>Quality</td>
<td>Item</td>
<td>££</td>
<td>Variations</td>
<td>Item</td>
<td>££</td>
<td>various</td>
<td>££</td>
<td></td>
</tr>
<tr>
<td>Transp ort</td>
<td>Item</td>
<td>££</td>
<td>Site Welfare</td>
<td>Item</td>
<td>££</td>
<td>Enviro ditto</td>
<td>Item</td>
<td>££</td>
<td>Risk</td>
<td>Item</td>
<td>££</td>
<td>Teamwork</td>
<td>Item</td>
<td>££</td>
<td>Management</td>
<td>Item</td>
<td>££</td>
</tr>
<tr>
<td>Enviro ditto</td>
<td>Item</td>
<td>££</td>
<td>Plant</td>
<td>Item</td>
<td>££</td>
<td>Testing</td>
<td>Item</td>
<td>££</td>
<td>Co-Ordination</td>
<td>Item</td>
<td>££</td>
<td>Supply chain</td>
<td>Item</td>
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<td>Item</td>
<td>££</td>
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<tr>
<td>Materia ls</td>
<td>Var</td>
<td>££</td>
<td>Productivity</td>
<td>Item</td>
<td>££</td>
<td>Commission</td>
<td>Item</td>
<td>££</td>
<td>Integrat ion</td>
<td>Item</td>
<td>££</td>
<td>Procurement</td>
<td>Item</td>
<td>££</td>
<td></td>
<td>Item</td>
<td>££</td>
</tr>
<tr>
<td>Site Labour</td>
<td>Hrs</td>
<td>££</td>
<td>Enabling wk</td>
<td>Item</td>
<td>££</td>
<td>Safety</td>
<td>No</td>
<td>££</td>
<td>Cost-in-Use</td>
<td>Item</td>
<td>££</td>
<td></td>
<td>Item</td>
<td>££</td>
<td></td>
<td>Item</td>
<td>££</td>
</tr>
</tbody>
</table>

**KEY: Added Value Descriptors**
- ££ Efficiency
- ££ Effectiveness
- ££ Performance
- ££ Cost-in-Use
- ££ Various
### TABLE 4: Measurement of Plant as Part of a Component Comparison

<table>
<thead>
<tr>
<th>Pre-Assembled Service Modules Comprising:</th>
<th>Traditional Construction comprising:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air handling unit, duct &amp; pipework, vent &amp; extract grilles, controls, power &amp; light supply, insulation, testing, protection, primary and secondary steel framing, painting</td>
<td>Measurement of each item separately:</td>
</tr>
<tr>
<td>Plant required during manufacture:</td>
<td>Unloading &amp; Storing Materials - repeated for all materials</td>
</tr>
<tr>
<td>INCLUDED IN MODULE COST</td>
<td></td>
</tr>
<tr>
<td>Plant required for moving on site:</td>
<td>Transporting &amp; lifting to position - ditto</td>
</tr>
<tr>
<td>INCLUDED IN INSTALLATION</td>
<td></td>
</tr>
<tr>
<td>Plant required for installation:</td>
<td>Equipment needed to fix in position - ditto</td>
</tr>
<tr>
<td><strong>Crane</strong> - lift from delivery lorry</td>
<td></td>
</tr>
<tr>
<td>Hrs/module per crane type</td>
<td></td>
</tr>
<tr>
<td><strong>Crane</strong> - lift into permanent position &amp; support</td>
<td></td>
</tr>
<tr>
<td>ditto</td>
<td></td>
</tr>
<tr>
<td><strong>Weld/bolt</strong> - fix steel framework</td>
<td></td>
</tr>
<tr>
<td>Hrs/module plant specified</td>
<td></td>
</tr>
<tr>
<td><strong>Connect</strong> - duct/pipe/cables module to module</td>
<td></td>
</tr>
<tr>
<td>ditto</td>
<td></td>
</tr>
<tr>
<td><strong>Crane</strong> - remove packaging</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Allow</strong> - standing time, double handling</td>
<td><strong>Allow</strong> - standing time, double handling (RISK ITEM)</td>
</tr>
<tr>
<td>(RISK ITEM)</td>
<td>For each item - Contingency required %age addition</td>
</tr>
<tr>
<td>Contingency required</td>
<td>%age addition</td>
</tr>
</tbody>
</table>
TABLE 5: Benefit Evaluation Matrix for Use at Detailed Level

<table>
<thead>
<tr>
<th>Importance of Factor</th>
<th>Score</th>
<th>A. Environmental impact across delivery supply chain</th>
<th>B. Environmental impact at site level</th>
<th>C. Certainty of delivery</th>
<th>D. JIT delivery</th>
<th>E. Supply chain location</th>
<th>F. Likelihood of pre-assembly improving performance in these issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imperative - is an overriding factor influencing the design and/or procurement decision</td>
<td>9 - 10</td>
<td>Client is high profile green</td>
<td>Ditto</td>
<td>Contract period main remen for pull down menus for identified factors or insert own (help given)</td>
<td>Will contribute highly where certainty of delivery a priority</td>
<td>Will contribute highly where JIT &amp; green issues important</td>
<td>Yes, in all building elements</td>
</tr>
<tr>
<td>Very Important - should be a major influencing factor in design/procurement choice</td>
<td>7 - 8</td>
<td>Client is committed green</td>
<td>Ditto</td>
<td>time not a driving factor in procuremen t</td>
<td>Should be encouraged as will contribute to Client benefit</td>
<td>Should be encouraged as will contribute to Client benefit</td>
<td>Yes, in some building element</td>
</tr>
<tr>
<td>Quite Important - should influence design/procurement choice</td>
<td>5 - 6</td>
<td>Client</td>
<td>Ditto</td>
<td>Benefit will be accrued lower down delivery supply chain and may reach Client</td>
<td>Benefit will be accrued lower down delivery supply chain and may reach Client</td>
<td>Benefit will be accrued lower down delivery supply chain and may reach Client</td>
<td>Yes, in (named) element</td>
</tr>
<tr>
<td>Important - should be considered in decision</td>
<td>3 - 4</td>
<td>Client does not ignore green issues</td>
<td>Ditto</td>
<td>Lowest score recommend ed for this factor</td>
<td>Implemente d for benefit of delivery supply chain no benefit to Client</td>
<td>Implemente d for benefit of delivery supply chain no benefit to Client</td>
<td>Unknown</td>
</tr>
<tr>
<td>May be important if combined with other factors (named as:)</td>
<td>1 - 2</td>
<td>Client views this as a bonus but not essential</td>
<td>Ditto</td>
<td>Unlikely to occur</td>
<td>Only of benefit to certain members of delivery supply chain</td>
<td>Only of benefit to certain members of delivery supply chain</td>
<td>Unlikely</td>
</tr>
<tr>
<td>Unimportant - discard</td>
<td>0</td>
<td>Client not interested</td>
<td>Ditto</td>
<td>Unlikely to occur</td>
<td>No benefit to any party</td>
<td>No benefit to any party</td>
<td>Not at all</td>
</tr>
</tbody>
</table>