A DECISION SUPPORT MATRIX FOR BUILD SYSTEM SELECTION IN HOUSING CONSTRUCTION

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ABSTRACT

The increasing demand of housing supply in the UK drives the industry to consider using more alternatives of build systems. However, the selection of build systems appears to be normally left to late design stages, which may expose the business to undesirable risks. This paper aims to improve build system selection by introducing a transparent structured decision support matrix. A number of interviews with leading house builders were used to examine the decision criteria and establish mechanisms of selection. These firms, together, contribute a tenth housing unit completions by the industry overall. The paper develops the matrix which provides over 50 value-based criteria for system selection and methods for calculating weights of criteria and scores of systems. The matrix can be used as a tool for system selection in early design processes, which should help improve efficiency and mitigate risks for housing construction.

Key words: Build system selection, Decision criteria, Decision support matrix, Housing construction.
Introduction

The number of UK housing completions has been on a downward trend since the 1960s (ODPM, 2005). However, the number of households has been forecast to increase by 3.8 million between 1996 and 2021, equivalent to around 150,000 each year (DETR, 2000). Recent statistics even show that on top of the previous estimate there will be 39,000 more new households formed in the UK each year (Barker, 2003; ODPM, 2005). The under-supply of housing underlines the need to build more homes to meet the needs of housing demand and the economy (Barker, 2004; ODPM, 2005). This combined with the evolutionary change of the policy and planning context (see ODPM, 2005; DCLG, 2006) drives the house building industry to review their way of working and to seek alternative approaches to delivering high quality, sustainable housing in a more productive manner. However, the decision-making of selecting build systems appears to be normally left to late design or pre-construction stages due to a lack of knowledge and the predominant use of financial criteria. Late or wrong decisions may exploit new build systems inappropriately and expose the business to undesirable risks. Within this context this paper contributes to knowledge by presenting a decision support matrix for selecting build systems for housing construction. The paper reports on research into the selection of build systems including traditional masonry, timber frame, pre-cast concrete cross wall, and sandwich concrete panels for houses/low-rise apartments and mid-rise apartments. This should help house building organizations achieve a structured balanced decision-making of selecting appropriate build systems with potential risks mitigated.

Decision Support Systems

Many decisions are too complex or too important for decision-makers to make choices based solely on instinct and past experiences. A Decision Support System (DSS) can structure the decision-making process, improve the quality of the information on which the decision is based, and, thus, allow decision-makers to understand the nature of problems better so that they can make better decisions (Turban and Aronson, 2001). The design of such tools/systems needs to address the challenge that they should perform “complex functions”, but also are simple to use, “preferably with minimal training or change to their existing method of working” (Pasquire et al., 2005: 482). Li and Love (1998) suggested that, fundamentally, DSS are systems designed to support decision makers, and there are two basic approaches to developing decision support systems: operations research (OR) and artificial intelligence (AI). Attention to DSS research in construction is rising, having been shaped largely by the advances in Information Technology (IT). Many IT based DSSs have been developed to support decision-makers in construction in gathering information, identifying available alternatives, and selecting the optimal solution (Li and Love, 1998). However, this body of knowledge appears to have overlooked the area of build system selection in house building. There also exists a lack of research
that combines the use of OR and AI approaches in addressing complex decision problems.

It is generally accepted that knowledge is a vital organizational and project resource that gives market leverage and contributes to organizational innovations and project success (Egbu, 1999). It is often possible to use past knowledge and expertise to expedite decision-making. Therefore, it does not make sense to ‘reinvent the wheel’ each time a decision is made (Turban and Aronson, 2001). This is significant given the challenges facing decision-making, including more alternatives to choose from, more uncertainties about the future, larger costs of making mistakes and requirements for quick decisions. The development of decision support systems should hence embody the philosophy of managing knowledge, regarding knowledge management as an asset rather than a liability (Anumba et al., 2005). Knowledge management can also promote organizational learning, leading to further knowledge creation. Therefore, it is of great importance for decision support systems to facilitate the management of these two types of knowledge and the conversion of tacit knowledge to explicit for organizational learning (see Turban and Aronson, 2001). The structured decision-making process enables transparency of the process and the accumulation of knowledge in a manageable and reusable manner.

**Build System Selection**

A number of publications have emphasized the importance of early decision-making to realizing the potential benefits from offsite (e.g. Gibb, 1999; Neale et al., 1993; Sparksman et al., 1999). However, in practice, late decisions are often made by stakeholders including clients (Gibb and Isack, 2003) and their professional advisors (Pan et al., 2004). This is significant given that there are currently over 100 offsite systems, being supplied by over 300 offsite manufacturers and suppliers in the UK market (Mtech Group, 2004a). Furthermore, this situation is worsened by the fact that information on different build systems is normally limited at conceptual design stages. The decision-making involves various house building stakeholders (Pan et al., 2007), uses a large number of tangible and intangible factors of consideration (Gibb and Pendlebury, 2005; Soetanto et al., 2006), and is constrained by limited resources of house building organizations (POST, 2003). It is very unlikely for any single decision-maker to meaningfully combine all of this information and make informed decisions. House building firms, particularly in the private sector, tend to leave their decision-making as late as they can to reduce financial risks. Therefore, house builders are concerned with how to manage risks and avoid wrong early decisions with regard to the selection of offsite techniques. This importance of BSS has also been emphasized by offsite consultants in the market that a wrong decision on offsite system selection during design processes may exploit a new technology inappropriately and expose the business to unacceptable levels of innovation risk (Mtech Group, 2004b; Richards, 2004). Recent research (Ilozor et al., 2004) suggests that there is a positive relationship between residential house defects and the structural
framing used. These studies, altogether, reveal that selecting appropriate build system for house building is very critical.

There appears to be a lack of knowledge of BSS in house building. A comparative study of models/processes on selecting construction systems, methods or materials is provided in a parallel paper. This paper presents the observations of the decision criteria and methods for weighting and scoring due to the words limit. There appears to be a lack of rational, robust and balanced decision criteria for build system selection in house building. This is understandable given the current lack of research into decision-making in build system selection in house building. Also, such a selection is often based on cost rather than value (Pasquire et al., 2004). Though many criteria were used for assessing construction systems and methods, they are largely constrained to technical processes from designers’ perspectives (see e.g. Nassar et al., 2003) and/or construction processes (see e.g. Idrus and Newman, 2002; Rogers, 2000). Soetanto et al. (2004, 2006) provided a list of criteria for structural frame selection, drawing on existing knowledge and the perspectives of wide practitioners including clients, designers and contractors. This contributes to achieving a more objective and systematic frame selection by project team participants. However, the list of criteria lacks an input of the organizational business context, e.g. criteria on supply chain management and acceptance of insurers and financers. These organizational business criteria are too significant to decision-making in system selection in house building to be implicit or overlooked. Also, many criteria used in previous research are presented in general terms, e.g. cost and time, but no clear explanations are provided. This raises concerns over the reliability of measurements obtained since the criteria in general terms are in effect mutually interactive. It has been demonstrated that decisions to compare traditional and offsite solutions for construction in general are largely based on material, labor and transportation costs, whilst other cost-related items such as site facilities, crane use and rectification of works are disregarded, and softer issues such as health and safety, effects on management and process benefits are either implicit or disregarded (Blismas et al., 2006; Pasquire and Gibb, 2002). Birkbeck and Scoones (2005) claimed that, although the technical criteria for selecting one approach over another often tend to be overridden by circumstances in the UK, criteria including cost, supply, technical considerations, building height do play a part in helping designers and builders decide the most appropriate structural form. Aesthetics are rarely a consideration, as the structural systems are seldom expressed as part of the overall external presentation of the buildings (ibid). It has also been argued that steel structures provide greater resource efficiency than concrete or all-timber structures (Prewer, 2005). The availability of materials, in this sense, could be another criterion for build system selection, but it is less relevant to decision-making in the organizational context. Taking all these studies together, though a wide range of factors of consideration have been identified in previous research, there is still a shortage of systematic, balanced, rational criteria for the decision-making in build system selection in house building.
Previous studies present the use of a variety of scoring and weighting methods. However, the use of the scoring and weighting methods is not justified in most of the studies. The lack of rational, justifiable weighting of decision criteria also exists in industry practices. As identified by Pasquire et al. (2005), “there still seemed to be an expectation that a building not only could but had to fulfill all and every aspect of a Client’s “wish list” with equal weighting”. They also found that project team members were all approaching a project with an individual view of benefits rather than a project view of value.

The review has revealed a very limited amount of knowledge available at the moment of build system selection in house building. A direct effect of this on house building organizations is that they have to rely on their past experience and professional knowledge for decision-making. This inhibits the take-up of offsite techniques and systems. Though there exists some degree of understanding of the decision-making process in some organizations, there remain significant areas for improvement. These are centred on the overall decision-making process, decision criteria, weighting and scoring methods, and results examination and validation. Therefore, there is a need to improve the decision-making in build system selection. This is significant given the current under-supply of housing and the slow take-up of offsite technologies in the industry. Considering the existing knowledge base and the rate of general taking up ideas and innovations by the industry, the improved approach to decision-making is suggested in the form of a practical tool supported by a series of ‘soft’ checklists and databases. Within this context this paper aims to make contributions to achieving an improved design decision-making of selecting build systems by introducing a transparent structured decision support matrix.

**Methodology**

The research aim has been achieved by using a qualitative research type in the form of interview-based study (see Bryman, 1989). Document analysis was used where necessary. A number of face-to-face interviews were carried out with the senior technical directors/managers of six leading house contractors. Through the interviews decision criteria were examined and mechanisms of selection were established. These firms, together, contribute over a tenth housing unit completions by the industry overall (Table 1).

All firms had used offsite technologies considerably for their housing projects during the past three years. The integration of the offsite approach to build processes had been taken on board within all of the companies. On behalf of their companies senior managerial or technical staff attended the interviews who were involved in decision-making for selecting build systems for their housing projects. Five out of six senior managers had been involved in at least one Government-backed offsite/modern methods initiative, some taking the role of chairing their study groups. The other one had been heavily involved in the manufacturing industry and was currently exploring
their offsite applications. For the purpose of confidentiality, all of the participant companies are referred to with letters. The data collected are largely qualitative in nature, and were analyzed from which appropriate themes and patterns were identified (see Patton, 2002). For weighting and scoring quantitative data were also obtained. The methods of handling such data are provided in the section of results.

### Table 1: Details of interviewed house builders

<table>
<thead>
<tr>
<th>House builder</th>
<th>Unit completions</th>
<th>Turnover (£m)</th>
<th>Position of Interviewee</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6,238</td>
<td>1,182</td>
<td>Head of R&amp;D</td>
</tr>
<tr>
<td>B</td>
<td>6,044</td>
<td>773</td>
<td>Group Product Development Manager</td>
</tr>
<tr>
<td>C</td>
<td>2,691</td>
<td>461</td>
<td>R&amp;D Director</td>
</tr>
<tr>
<td>D</td>
<td>1,854</td>
<td>456</td>
<td>Group Technical Manager</td>
</tr>
<tr>
<td>E</td>
<td>1,085</td>
<td>232.9</td>
<td>Director of Innovation</td>
</tr>
<tr>
<td>F</td>
<td>877</td>
<td>145.6</td>
<td>R&amp;D Manager</td>
</tr>
<tr>
<td>Total of interviewed firms</td>
<td>18,789</td>
<td>3,250.5</td>
<td></td>
</tr>
<tr>
<td>The industry as a whole</td>
<td>175,600</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage</td>
<td></td>
<td>10.64%</td>
<td></td>
</tr>
</tbody>
</table>


R&D – Research & Development

### Analysis and Results

#### Current Decision-Making Approaches

The decision-making approaches currently taken by the participatory house builders were identified within the context of build system selection. All of them relied upon heuristic decision-making, drawing on individual experience and intuition, and informal group discussion. Two companies had used some simple tools like best practice templates and estimate workbook. None had used any formal decision-making software like Expert Choice. No company had applied any sophisticated decision theories such as utility theory, linear programming, fuzzy sets or Bayesian analysis. However, all of the companies used, to a varied degree, external management consultants for decision support.

#### Decision Criteria for Build System Selection

The results suggest that a cost-driven approach was applied traditionally for such decision-making, whilst other important aspects, such as health & safety and sustainability, have been neglected. The paper develops a decision support matrix which provides over 50 value-based criteria for system selection under eight main
headings including cost, time, quality, health & safety, sustainability, process, procurement and statutory acceptance (see Figure 1). An overall top-down approach was used for the identification of decision criteria. The top-down approach is to ask about the aim, purpose, mission or overall objectives that are to be achieved (Dodgson et al., 2000). The use of this approach was considered as appropriate for the case of selecting build systems as there had already existed performance objectives in the industry overall and benchmarking KPI targets in the participatory companies.

The identified decision criteria, in the structure of a value tree, were presented and explained to the interviewees for comments. All of the interviewees agreed with the researcher that the criteria, the sub-criteria and the hierarchy illustrated the current industry concerns over the use of offsite well and comprehensively, and, thus, could be used ideally as a checklist by house building organizations for build system selection. The discussion with the interviewees suggested that the criteria model could help house building organizations mainly in the following aspects:

- It structures the thinking of selecting appropriate build systems for specific projects.
- It clarifies the value management structure of the company.
- It provides a checklist of collecting ‘what’ information from ‘where’ and by ‘whom’.
- It presents a framework for measuring the performance of offsite technologies.

The interviewees also provided some extra factors for consideration and/or amendments to the hierarchy according to the practices of their companies. This enriches the practicality of the criteria model and expands further the coverage of the decision-making factors. Some of the extra factors provided are actually covered by other existing criteria in the model, but some supplement the original thinking and, thus, are taken on board for refining the model (Figure 1).
Figure 1: Build system selection matrix

<table>
<thead>
<tr>
<th>Item</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 1</td>
<td></td>
<td></td>
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<tr>
<td>Item 2</td>
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<td>Item 3</td>
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<td>Item 4</td>
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<td>Item 5</td>
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<td>Item 6</td>
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<td>Item 7</td>
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<td>Item 8</td>
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<tr>
<td>Item 9</td>
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<td>Item 10</td>
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</tbody>
</table>

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Weighting Methods Used

Four methods were used for weighting criteria in this study, namely, Top-down Direct Rating (TDR), Bottom-up Direct Rating (BDR), Point Allocation (PA) and Analytical Hierarchy Process (AHP) (see e.g. Saaty, 1980; Barron and Barrett, 1996; Roberts and Goodwin, 2002). The detailed study of the advantages and limitations of these methods is provided in a parallel paper. The key observations of utilizing these methods in this study are provided as follows:

- The combined use of the methods TDR and PA was considered to be the most appropriate approach for weighting criteria in this study.
- The method AHP would be good for weighting the criteria theoretically. However, a large portion of the results in the study were checked inconsistent, with their consistency ratios > 0.1 (Saaty, 1980). The use of AHP would also require substantial, prior training on using the technique. Therefore, AHP is not recommended for use in the case in the first instance.
- However, it would be helpful to use AHP for weighting the criteria at the objective level. The results obtained could be used to countercheck that from using the other methods.

The analysis of the weighting process explores the participants’ perspectives of the importance of the criteria and their propensity for weighting. The results from different companies provide a way to triangulate the validity and reliability of the data. This will be taken for discussion late in this paper.

Scoring Methods Used

Several methods were considered for measuring the build systems for this study but just the methods Direct Rating (DR) and Pair-wise Comparison with single benchmark (PC) were used. The selection of scoring methods was based on the following considerations:

- The final outcome expected from the measurement process was ‘accurate’, ‘absolute’ measurements based on the use of interval scales, not just ranks obtained from ordinal scales. The interval measurements were supposed to be calculated with weights to deliver weighted scores for build system selection. This consideration ruled out the use of methods such as Direct Ranking and AHP.
- The method Structural Sifting should be always used before detailed scoring exercises are carried out.
- The method Direct Scoring was applicable for obtaining scores for options against quantitative and monetary criteria. However, the method was not used for the workshop event because only qualitative measurements were collected through the exercise.
Construct a Performance Matrix of Build Systems

The performance of the build systems was measured and the measurements were integrated into a matrix which is called performance matrix. The original measurements were verbal expressions obtained from using a 7-point rating scale. The use of verbal expressions eased the performance measuring process for the participants. It also suited the context of measuring against the criteria, most of which were qualitative in nature. The combined use of DR and PC involved the use of two scales: one for direct measurement and the other for relative measurement. This was based on the assumption: the participants are most familiar with one of the build systems, and feel most confident and comfortable to measure this system directly. This system is called benchmark system. For other systems, the participants can provide measurements by comparing to the benchmark. This approach helps improve the validity of data when participants lack information and feel difficult to provide direct judgments. The performance descriptions of the build systems against the criteria were also collected and stored in a performance database of build systems for house building. These qualitative descriptions underlay the measurements in grades provided by the participants. This database helps capture the case company’s knowledge of a number of build systems in relation to housing construction, which provides the company with an effective mechanism for learning and knowledge sharing across projects/teams. The database should be reviewed and updated on a regular basis.

In simple decision-making circumstances, the performance matrix may be the final product of the process. Decision-makers may make judgment on which system meets decision objectives better. For complex decision problems which involve dozens of criteria and options, such intuitive processing data may lead to the use of unjustified assumptions, causing incorrect ranking of options. Sometimes, the large number of criteria and options is simply overwhelming for decision-makers to make selections. Under such circumstances, more scientific methods have to be used to facilitate handling complex performance measurement data. This is explained in next section.

Transform Verbal Expressions to Calculable Scores

The models for transforming verbal expressions to numerical scores abound in the literature. They basically differentiate from each other in two areas: first, whether the models for transforming are linear or nonlinear, and second, whether they are expressed in absolute measurements or in fuzzy sets. Though the tool attempts, ideally, to offer the end-user the flexibility to define their own model for transforming scores, the linear model with absolute measurements was used for the study. This was based on the considerations as follows:

- The linear model is simpler and easier-to-use than non-linear models, so is the use of absolute measurements than the use of fuzzy sets.
• Both absolute and fuzzy set measurements are subjective measurements. They are just different approaches to expressing measurements; one is by absolute values but the other by ranges of values. They follow different calculation rules.
• The BSS tool overall aims to support decision-making not to generate decisions. The results obtained by using the tool are subject to decision-makers’ verifications. Therefore, more sophisticated techniques are not favored in this case.
• Decision-making in house building organizations is currently largely based on the heuristic approach. The proposal for improvement should be simple, direct and easy to understand.

Combine the Weights and Scores

The Linear Additive Model was used in the study for producing overall weighted scores for its simplicity and general acceptance. This is also because the weighted scores produced were for decision support purpose rather than decision offering. The overall preference score for each option is simply the overall weighted score of the option against all of the criteria. The formula below presents the calculation (see e.g. Keeney and Raiffa, 1976; Dodgson et al., 2000).

\[ S_i = w_1 s_{i1} + w_2 s_{i2} + \ldots + w_n s_{in} = \sum_{j=1}^{n} w_j s_{ij} \]

Keys:
- \( S_i \): Preference score for option \( i \)
- \( s_{ij} \): Performance score of option \( i \) against criterion \( j \)
- \( w_j \): Weight of criterion \( j \)
- \( n \): Number of criteria

In words, the overall weighted score for an option can be obtained through: firstly, multiplying an option's performance score against a criterion with the weight of that criterion, secondly, repeating that for all of the criteria, and finally, summing all of the weighted scores of that option.

Present the Weighted Scores

The formula and the process have taken the assumption that the weighted scores against all decision criteria are aggregated to produce a single overall weighted score of preference. However, the discussion with the interviewees shows that this is not necessarily required by decision-makers. They may wish to produce a weighted score for each group of criteria, e.g. for cost, time, quality etc. This will provide decision-makers with a simple matrix ‘Decision Support Outcomes Matrix’. This is significant when some of the performance measurements are not in verbal expressions but in
objective, quantitative data. For example, quotations of cost and build program may be provided by system manufacturers/suppliers at early design stages. In this case, it will be unwise to transform the exact, objective data into preference scores because such a transforming process would cause errors. Therefore, the final decision support outcomes may need to be presented under a few groups including quantitative and monetary, e.g. cost, quantitative but not monetary, e.g. time and health & safety, and qualitative, e.g. quality.

Discussion

Decision Criteria for Build System Selection

This paper has provided a hierarchy of decision criteria for build system selection in house building, which takes into account the business context of house building organizations. This addresses the current lack of knowledge of rational, robust and balanced criteria. At the macro level, the study is consistent with the existing body of knowledge as it has taken the high-profile concepts of cost, time, quality, health & safety, sustainability, process, procurement, and regulatory & statutory acceptance as the main objectives for decision-making in system selection. These concepts have been contextualized into the house building business in the study. At the micro level, the study breaks the eight objectives down into 35 criteria, some being further broken down into sub-criteria for clarity. This provides a clear, structured analysis of decision criteria for build system selection. The process of clustering criteria incorporates the use of the knowledge base existing in the industry domain and the data collected from the large house builders investigated. The results reveal that the decision criteria actually interact with each other, and, thus, must be clearly defined and explained in order to structure understanding and ensure consistent measurements. The research outcome should help improve the understanding of decision criteria for build system selection in house building.

Weighting Methods

The results show that the independent variable ‘decision-makers’ is determinant for the dependent variable ‘decision weighting outcomes’. With specific decision-makers, the use of different weighting methods produced similar weighting outcomes that are highly correlated. However, with different decision-makers, the weighting outcomes became substantially different even when the same weighting methods were used. This finding seems to be in disagreement with the argument made by Roberts and Goodwin (2002) that the accuracy of weights is based on particular assumptions about how decision-makers’ ‘true’ weights are formed. This disagreement is probably attributable to the use of the step of examining results in the BSS exercise. The interviewees were required to examine if the weights obtained reflected their perceptions of the degree of importance of criteria to addressing the decision problem. However, much previous research into weighting methods (e.g. Roberts and
Goodwin, 2002) does not include such an examination step. Also, the results suggest that no single weighting method will deliver the ‘true’ weights. Again, which set of weighting outcomes to use is subject to the final examination by decision-makers. This argument reflects the nature of decision-making in build system selection that house builders aspired for a transparent process rather than any sophisticated methods. The results therefore justify the initial consideration not to use sophisticated weighting methods for the tool.

The interviews suggest that the combined use of the methods TDR and PA is most appropriate for weighting criteria for build system selection. In this approach, TDR is used to weight criteria when the number of criteria is four or more, whilst PA is used when the number is four or less. This is because of the nature of PA that it may generate conflicting weights and, thereby, requires iterations of allocating points. This finding confirms the declaration in previous research (e.g. Doyle et al., 1997; Roberts and Goodwin, 2002) that point allocation is a more difficult task than direct rating and decision-makers are constrained by the specified total value. However, the results show that this is not always true and the use of PA becomes fairly simple and direct when weighting two or three criteria. The weighting outcomes from the study reveal that the use of PA generally generates wider spread of weights than the direct rating methods do, despite the same rank. This appears to be consistent with the conclusion of the study by Doyle et al. (1997: 71) that “PA and Rating lead to different profiles of weights”.

Process of scoring

The process of measuring performance of build systems and scoring in the study can be simplified into two three stages linked by two transformations. The first is to transform performance measurements in verbal expressions into numerical scores. The second is to transform numerical weighted scores into verbal grades of results (Figure 2).

![Figure 2: Process of measuring and scoring](https://example.com/figure2)

The decision support matrix provides a mechanism for obtaining final verbal grades of results using initial performance measurements in verbal expressions. The first
The methods Direct Rating (DR) and Pair-wise Comparison (PC) were used for measuring performance in this study. The participants claimed that the use of DR was direct, simple and easy-to-understand, whilst the use of PC was more difficult since it required the procedures of pair-wise comparisons and the transformation from relative measurements into absolute measurements. This result echoes the observation of Podinovski (2002) that no rigorous definition of the concept of relative importance has been introduced and the use of the concept is relied on an intuitive understanding. The study does not join the debate over the measurement scales for pair-wise comparisons in which many studies attempt to provide mathematical models to elicit ‘true’ preferences of decision-makers (see Leskinen, 2000). Instead, the study used a simple, linear model for transforming relative measurements into absolute measurements. However, the results still suggest decision-makers’ reluctance to using it. One of the reasons may be due to the general low level of usage of any decision support methods/techniques in house builders. This suggests a potential area where further research may be carried out.

All interviewees preferred to use a linear model for transforming verbal expressions into numerical scores. Most of them also argued that different people would have different preferences over scores so that the use of non-linear models would confuse people. However, some interviewees used modified versions of the original transformation scale. All of the modified scales are highly correlated with each other, but are different in terms of the design of their start and end points, and their range.

Though it could be argued by positivists on the generalization of the results, they do provide the perspectives of a few large house builders’ on the performance of a series of build systems. The results are representative of the industry perspectives since the companies contribute a tenth of the housing unit completions by the industry overall anyway (see Table 1). However, for any further interpreting the results, the reader is warned here that a company-to-company comparison may need to take into account factors other than the final overall weighted scores. This is because the companies may have diverse business emphasis on house types and build systems, or simply different perceptions of the quantitative presentations of assessments. The decision outcomes from using the matrix should be interpreted in the approach of ‘replication logic’ (see Yin, 2003). In effect, this ‘replication logic’ provided by the use of the matrix reflects the ‘true’ picture of using offsite systems in the industry. It confirms
the strategy provided by Mtech Group (2004b: 26) that “It is important to avoid copying the correct evaluation decision from one project across to the next. The factors that lead to a project team to correctly select the techniques on one project are rarely the same as the next”. A built-in function of improving learning of the process addresses the importance of learning, which confirms the statement made by Mtech Group (2004b) that no software tool will make up for lack of knowledge within the project team. This discussion point suggests the need to apply the matrix in a wider industry context, from which more data could be captured and, thus, used to increase the extent of both ‘replication logic’ and quantitative generalization.

Conclusion

Conventionally there has been a limited amount of knowledge of build system selection for house building projects. A direct effect of this on house building organizations is that they have to rely on their past experiences and individual knowledge for decision-making. The current decision-making process is opaque and unstructured, in the lack of rationalized decision criteria. These factors, together, substantially inhibit the take-up of new, innovative build techniques and systems. This paper has contributed a robust, structured and transparent decision support matrix for build system selection in house building. This is significant given the current context in which the heuristic approach dominates decision-making in construction. The matrix provides more than 60 decision criteria clustered under headings of cost, time, quality, health & safety, sustainability, process, procurement, and regulatory & statutory acceptance. This matrix has also provided a successful example of applying the decision theories of business management sciences in housing construction, and speculates on an increased use of those theories to address problems in construction in the future. In terms of practical considerations, this paper has presented a reasonably ‘real’ picture of using offsite by house builders. It has unveiled the decision-making in build system selection of leading house building organizations. The decision-making process reflected in using the BSS matrix helps structure peoples’ thinking of using offsite, enhance organizational learning, and, thus, improve business efficiency. Also, the matrix provides a platform on which to capture performance of build systems in verbal assessments against the criteria. This should help decision-makers to obtain a quick, qualitative understanding of the build systems. Also the process transforms verbal assessments into scores, and integrates the scores and weights to produce overall weighted scores for each system.

The BSS matrix could be used in a wider industry context, by more organizations and/or more housing projects. The results obtained could enrich the databases of build system selection and enable the refinement of the tool to suit user requirements in a wider domain. This would improve the generalization of the tool as it was developed on a limited sample. The current version of the matrix could be developed into user-friendly, IT-based software.
The decision criteria for BSS and the decision support methods and techniques used in this study could be integrated into training programs of construction management-related disciplines. This would make a contribution to improving the decision-making in construction management, and thus help increase the uptake of offsite technologies.

References


