A NOVEL APPROACH FOR SELECTING FINISHES – SYSTEM ALGORITHM AND METHODOLOGY

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Motivated by the lack of effective tools that would facilitate the effective choice of building finishes taking into considerations various values to the client, an integrated approach for the selection of building finishes is proposed. First, critical requirements and processes for effective identification of decision criteria, generation of alternatives, and the decision-making process are identified. Then, the decision-making process is broken down into a logical series of activities. Then, various identified techniques/metrics are employed to model each activity and link it with other activities. The most unique feature of the approach is that critical stages of the decision-making process are automated and various scenarios of the decision making process are logically handled by a carefully designed algorithm.

Keywords: finishes, MCDM, value assessment, whole-life costing.

INTRODUCTION

Historically, the selection of finishes was mostly based on their initial capital costs. According to Dean (1996), building finishes is often regarded as a separate and final application to the fabric, sometimes even the last part of the building to be specified; and consequently may be subject to compromise in their quality by late cost-control exercises.

However, whole-life costs of buildings are significant, typically 3 to 10 times the capital cost (CIRIA, 1999). According to Kirk and Dell'Isola (1995), interior design and mechanical systems have the most significant impact on maintenance costs. This is one of many reasons that have pushed building owners, professionals and users to adopt whole-life costing. Other reasons include (Kirk and Dell Isola, 1995, Kishk et al., 2003):

- the emergence of a number of trends in the last decade as issues of concern for design professionals, such as facility obsolescence, environmental sustainability, operational-staff-effectiveness, and value engineering
- the expansion of new project delivery systems such as private finance initiative (PFI) and build, operate and transfer (BOT) in which the capital cost of construction is not separated from the running costs of projects anymore.
- the dramatic shift in the balance between the initial capital cost and the running costs of buildings towards a substantial increase in the running costs and the increased awareness among building users regarding the impact of this escalation on their budget.

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This fundamental desire to adopt a whole-life attitude regarding the design and management of buildings has faced a number of substantial obstacles that can be classified into two main categories. The first category relates to the basic nature of whole-life costing as it, by definition, deals with the future and the future is unknown. In a typical WLC exercise, it is normally required to forecast life expectancies of various components and systems, their future operating and maintenance costs, and discount and inflation rates. Major problems in doing so are: obtaining appropriate, relevant and reliable historical information and data; adjusting this data to the specific project at hand; and the analysis of various uncertainties in this data. Furthermore, the time needed for data collection and the analysis process may leave inadequate time for the essential dialogue with the decision-maker and the re-run of alternative options. This is one of the reasons why computerised WLC models are valuable (Griffin, 1993).

The second category relates to the way decisions are made within the construction industry. The design or component selection decisions can often be taken based on factors other than cost criteria, e.g. strength of materials, fire-protection, hygiene, health and environmental protection, safeguarding of use, sound isolation, energy saving and thermal isolation, durability and utilisation (Bogenstatter, 2000). Some of these factors may be reduced to a monetary scale and thus can easily be incorporated into whole-life costing calculations as monetary benefits in the usual way, i.e. by considering them as negative costs. For example, an earlier availability of the building for its intended use by selecting a particular alternative may be considered as a monetary benefit because of the resulting additional rental income and reduced inspections, and administrative costs (Lopes and Flavell, 1998). Most of these factors, however, cannot be assessed in a strict WLC framework. This is mainly because either they are in conflict with the main WLC objective or because they are mostly 'non-financial'. Some of these factors are even intangible such as aesthetics. In many cases, these intangibles are also in conflict with the results of WLC analyses (Wilkinson, 1996).

Recognising that subjective decision-making may destroy a complex and intricate WLC analysis, Dale (1993) recommends basing decision-making on a broader front than a simple economic analysis by utilising various methods of value theory. This view is supported by Langston and Ding (2001) who claimed that a means of assessing overall value is necessary such that the rationale for choices can be more objective and defendable.

There exist a number of methods that can be used to extend the WLC framework to consider non-financial factors to extend the WLC framework to consider non-financial factors. These methods were critically reviewed by Kishk et al. (2004). Each method seems to have some advantages and disadvantages. Besides, some of these methods do not take into consideration the relative importance of various decision criteria. Even, almost all methods that do so fall short from considering inherent uncertainties of the processes of eliciting weights of importance and ratings of alternatives.

In this paper, an integrated approach for the selection of building finishes is proposed. First, critical requirements for effective identification of decision criteria, generation of alternatives, and the decision-making process are identified. Then, the approach is outlined using simple process flow diagrams. Finally, the work is summarised and direction for further research are introduced. For convenience of the reader, various symbols used in the paper are summarised in an appendix

DECSION CRITERIA

Identification of Decision Criteria

A well-defined, small set of criteria is crucial for an effective decision-making process. They should be defined clearly in order to avoid confusion in their interpretation and to avoid double consideration of the same attribute. Keeney and Raiffa (1976) suggested general guidelines for generating and structuring criteria. Braunschweig et al. (2001) proposed a three-phase framework for criteria identification. The main idea is to capture as many relevant facets of the decision problem with the smallest set of criteria and consequently each phase results in a more specific list of criteria. This idea can be employed as follows (figure 1)

- In the first phase, the initial set of criteria is generated. Although there is no universal set of criteria that is equally applicable in all cases, standard checklists of system attributes are also useful in this initial phase. In these checklists, several criteria are classified in broad categories, e.g. safety, functional, sensible and practical. Criteria, however, must be closely linked to the project objectives and the performance problems being addressed. Codes of practice, project objectives and specifications, literature including legal and other official documents are crucial in identifying relevant criteria from checklists. In addition, an analysis of the space function and traffic requirements would help in compiling the initial criteria list. For example, abrasion resistance is relevant for areas with high traffic while static resistiveness is more relevant for areas with computers.
- In the second phase, criteria with no discrimination potential for the specific problem are excluded. These are usually criteria that are irrelevant, of negligible importance, or that measure the same dimension as other criteria.
- In the third phase, criteria applicability is evaluated in terms of data availability or ability to measure the criteria. The idea is to remove a criterion from the list rather than use poor or ambiguous indicators.

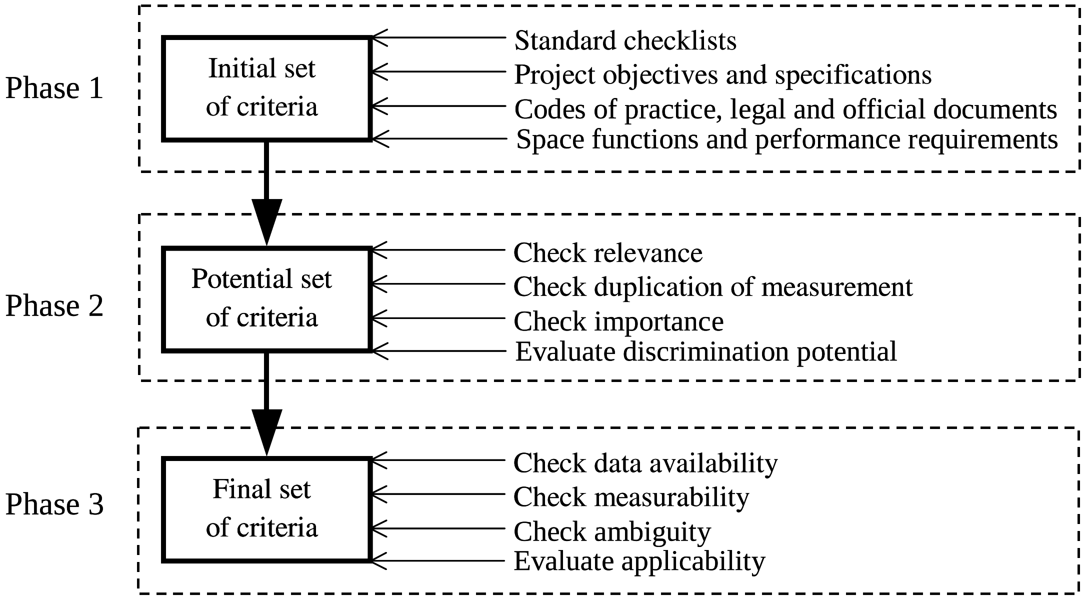


Figure 1: Schematic representation of the criteria identification process

Criteria Weighting

It is hypothesised that overall value can only be understood through a thorough examination of its constituent parts. In addition, although aspects of 'overall' or 'total' value can be extracted for analysis, the overall system is holistic in nature, and must be understood to be more than simply a sum of its parts (Laing, 1999). Rather, it should reflect their relative weights of importance. In the elicitation of weights of importance, criteria are rated for each criterion from 'most' to 'least' important. A direct scoring approach or a pair-wise approach is utilised. In the first approach, weights are directly assigned to various criteria. In doing so, a normalised scale (sums up to unity) is used to model various linguistic assessments of importance given by the decision-maker. In the pair-wise approach, however, each attribute is compared individually against all other attributes.

In addition to the fuzzy AHP, Triantaphyllou and Lin (1996) developed fuzzy versions of four more classical MCDM methods: the weighted-sum model (WSM), the weighted-product model (WPM), the revised AHP (RAHP) as proposed by Belton and Gear (1983), and the TOPSIS method (Hwang and Yoon, 1981). They tested the five methods against two evaluation criteria. The first evaluation criterion deals with the consistency of a method when single-dimensional problems are considered. The second evaluation criterion examines the stability of the results devised by a method when a non-optimal alternative is replaced by a worse one. Their analysis revealed that the more systematic approaches that employ pair-wise comparisons are more capable of capturing a human's appraisal of ambiguity when complex decision-making problems are considered. They attributed this to the flexibility and realism of pair-wise comparisons in accommodating real-life data.

Another crucial requirement is to use a normalised set of weights in calculating the total scores as recommended by Bass and Kwakernaak (1977). They employed the following normalised formula

$$S_i = \sum_{j=1}^{m} w_j s_{ij} \Big/ \sum_{j=1}^{m} w_j \tag{1}$$

where

S_i The aggregated rating for alternative $A_i, i = 1, n.$

w_j The weighing coefficient reflecting the relative importance of aspect a_j, $j = 1, m.$

s_{ij} The rating for alternative i, reflecting the relative merit of aspect a_j.

This formula has the desirable property that if the scores all are equal, the final weighted score is independent of the weights and equals the common value of the score.

GENERATION OF ALTERNATIVES

Obviously, the generation of a number of competing alternatives is crucial for the WLC exercise to be meaningful. Because the number of finishes' materials and products has been greatly increased in recent years, it is crucial to compile a balanced set of potential alternatives. This set should be neither too narrow to exclude potential ideal options nor too wide to increase the cost of data collection and analysis. To achieve that, a phased approach similar to that suggested for decision criteria can be employed such that each phase results in a more specific list of alternatives as follows.

- An initial alternative set is created from various sources including previous similar projects, various British standards, manufacturers and suppliers literature, and several other publications updated annually, e.g. the Architectural press, Barbour Microfile, RIBA Publications Ltd., the Building Technical File. Besides, the space function and performance requirements can help in the compilation process. For example, easily maintainable floor treatments such as vinyl composition tiles, ceramic tiles, and terrazzo can be considered in the initial potential alternative list to high traffic and high maintenance areas such as corridors, work areas, bathrooms, etc.
- In the second phase, alternatives are screened based on functionality and suitability criteria. The understanding of mechanics of deterioration and failure modes of finish materials is another crucial requirement for an easy specification of their correct application and use (Dean, 1996)
- In the third phase, alternatives that don't satisfy the minimum specifications, performance or statutory requirements are excluded. This can be done by indicating critical performance requirements (or thresholds) for finishes in different environments. Then, these thresholds can be used in the screening of unsuitable alternatives in the initial selection process. This will help in minimizing the number of alternatives considered and hence the time and cost of the detailed selection exercise. Alternatives that do not satisfy the financial constraints, e.g. budget restrictions, are also excluded. This can be done by specifying a maximum initial cost for specific finishes.

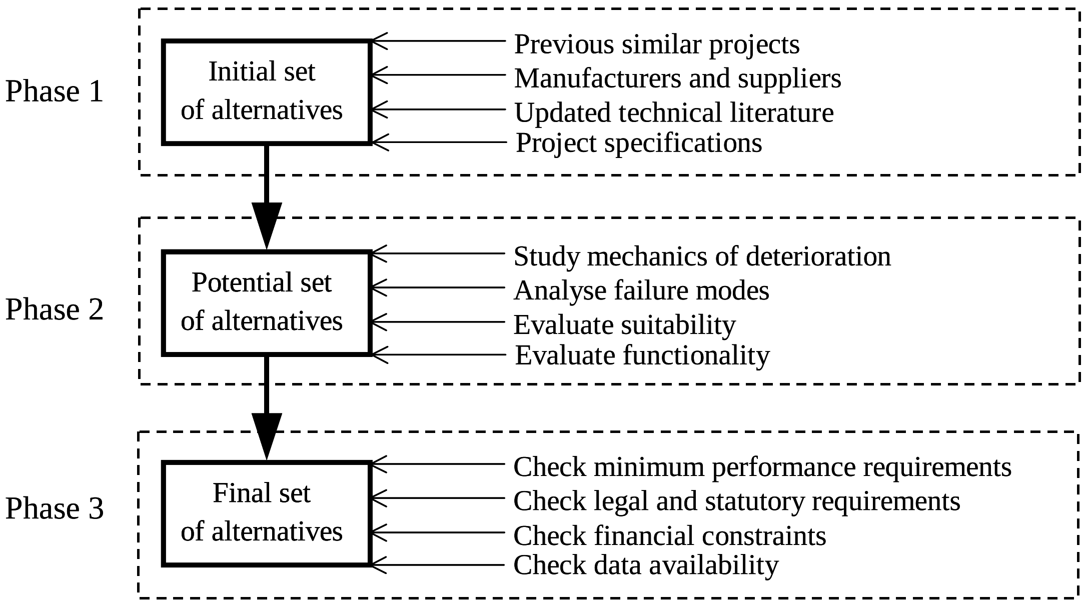


Figure 2: Schematic representation of the process of generation of alternatives.

ANALYSIS AND DECISION MAKING

Techniques

Classical MCDM methods require the determination of alternative ratings and criteria weights by eliciting the decision-maker (DM)'s judgements/preferences. In doing so, crisp values are commonly used to represent these ratings and weights, which are implicitly or explicitly aggregated by a utility function. The overall utility of an alternative represents how well the alternative satisfies the DM's objectives. The simplest and most employed function is the weighted average formula (equation 1). The best alternative, A^*, is determined as the one with the highest final rating, i.e.

$$A^* = A_i \left| S_i = \bigvee_{i=1,n} \sum_{j=1}^{m} W_j \cdot s_{ij} \right. \tag{2}$$

However, a means of assessing the overall value is necessary for an objective and defendable decision. In this sense, the traditional weighted average formula is not enough. Kirk and Dell'Isola (1995) recommend ranking alternatives according to their benefit to cost (BTC) ratios. A BTC ratio is calculated as

$$BTC_i = \frac{S_i}{WLC_i} \tag{3}$$

where WLC_i is the WLC measure of alternative i (NPV or EAC as appropriate).

Because a BTC ratio may be considered as a cost effectiveness measure, the ideal alternative, A^*, is selected such that it has the maximum index, which means maximum functional performance for minimum cost (Langston and Ding, 2001), i.e.

$$A^* = A_i \left| BTC_i = \bigvee_{i=1,n} \frac{S_i}{WLC_i} \right. \tag{4}$$

Despite this elegant interpretation, this approach can only be used if there is a single cost criterion to be considered. Besides, it does not reflect the relative importance of financial and non-financial attributes. Furthermore, the treatment of non-financial benefits is different from what is usually done in WLC regarding monetary benefits, i.e. by considering them as negative costs (Kishk, 2002). Kishk (2001) has shown that the use of BTC ratio is recommended in the case of uncertainty-tied alternatives. However, the use of the total combined score is crucial when no detailed cost results are available or when the relative importance of cost and non-financial criteria should be considered. It should be noted, however, that although a value-for-money metric should be used to make the final decision, other measures may be required in earlier stages of the decision-making process as discussed earlier, e.g. alternatives that do not satisfy the minimum technical and performance requirements are excluded regardless of their value-for-money metrics.

Handling Uncertainty

In order that an assessment of value can be regarded as having relevance within future projects, it is first necessary that the methods of assessment to be followed are clear, that they make a realistic use of data and that the range and depth of the information required is realistic. Indeed, even for simple cases uncertainty, long-term variability and risk should be recognised (Laing, 1999).

The uncertainty of various input parameters may produce a considerable decision uncertainty region. In such cases, competing alternatives are assumed to be tied, and some means of breaking the tie is needed (Kishk, 2001). In these cases, it is crucial to systematically analyse uncertain input data and provides the decision-maker with a better impression of their validity and usability by the employment of two sets of measures. The first set should include a ranking measure and a confidence measure to rank various competing alternatives and to evaluate the resulting rank order, respectively. The second set of measures should include appropriate uncertainty measures to assess the contribution of various parameters regarding the ambiguity of the decision. Then, the quality of the decision may be improved by seeking more 'precise and specific' information regarding these items only. By focusing on a smaller number of data items, the cost of undertaking the analysis can be greatly reduced (Kishk, 2001). It is interesting to note that all situations that require the consideration of non-monetary factors in WLC studies discussed above fit in the scope of application of MCDM methods as stated by Ekel et al. (1999).

Figure 3 shows schematically how various decision metrics/techniques can be effectively used in various stages of the decision making process.

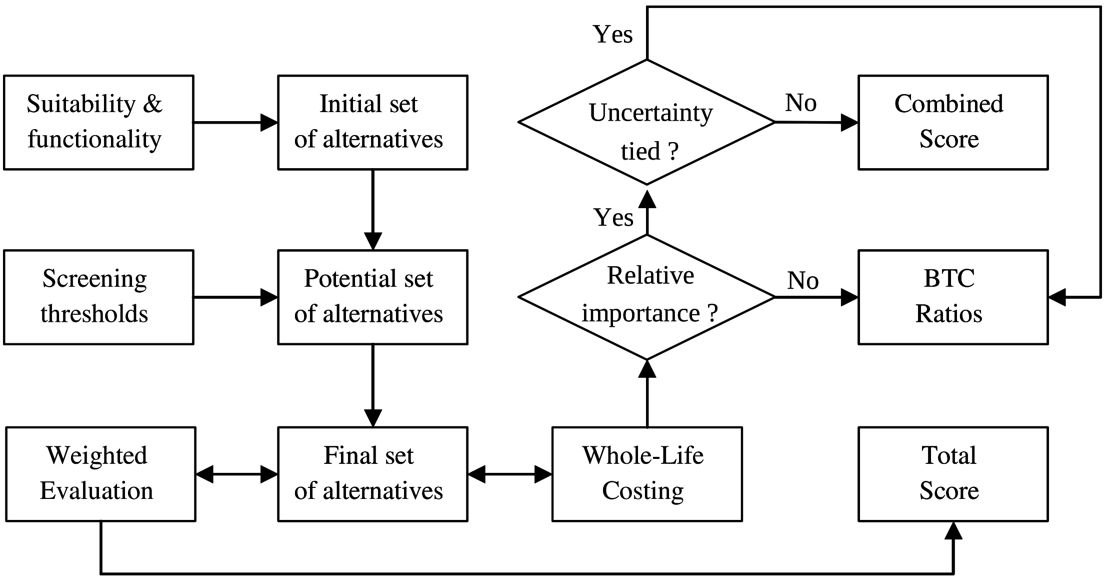


Figure 3: Schematic representation of the use of decision metrics and techniques.

A SELECTION ALGORITHM AND METHODOLOGY

Based on the above arguments, methodological algorithm may be proposed. Figure 4 shows a diagrammatic representation of the algorithm. As shown, five main phases can be identified: identification of criteria, generation of alternatives, analysis, ranking, and recycle phases.

- In the first phase, decision criteria are identified and grouped into two categories: screening and trade-off criteria. Screening criteria are those attributes that cannot be compromised because of limited resources, legal or minimum performance requirements. They are mainly quantitative criteria that might include financial, health and safety, statutory and technical criteria.
- In the second phase, all potential alternatives for the space/element under consideration are generated in three steps as discussed earlier. In the last step, the identified screening criteria are used to decide upon the final set.
- In the third phase, WLC analysis and weighted evaluation are carried out to calculate WLC measures and total scores for various competing alternatives.
- In the fourth phase, competing alternatives are ranked according to their BTC ratios or combined scores, as appropriate, and confidence measures in this ranking are calculated.

- The last phase is a recycle phase. If the ideal alternative is not clear as reflected by confidence measures in the ranking, uncertainty measures of various variables are calculated to identify those items that contribute significantly to the uncertainty of the decision. Then, the optimum improvement recycle loop(s) can be identified.

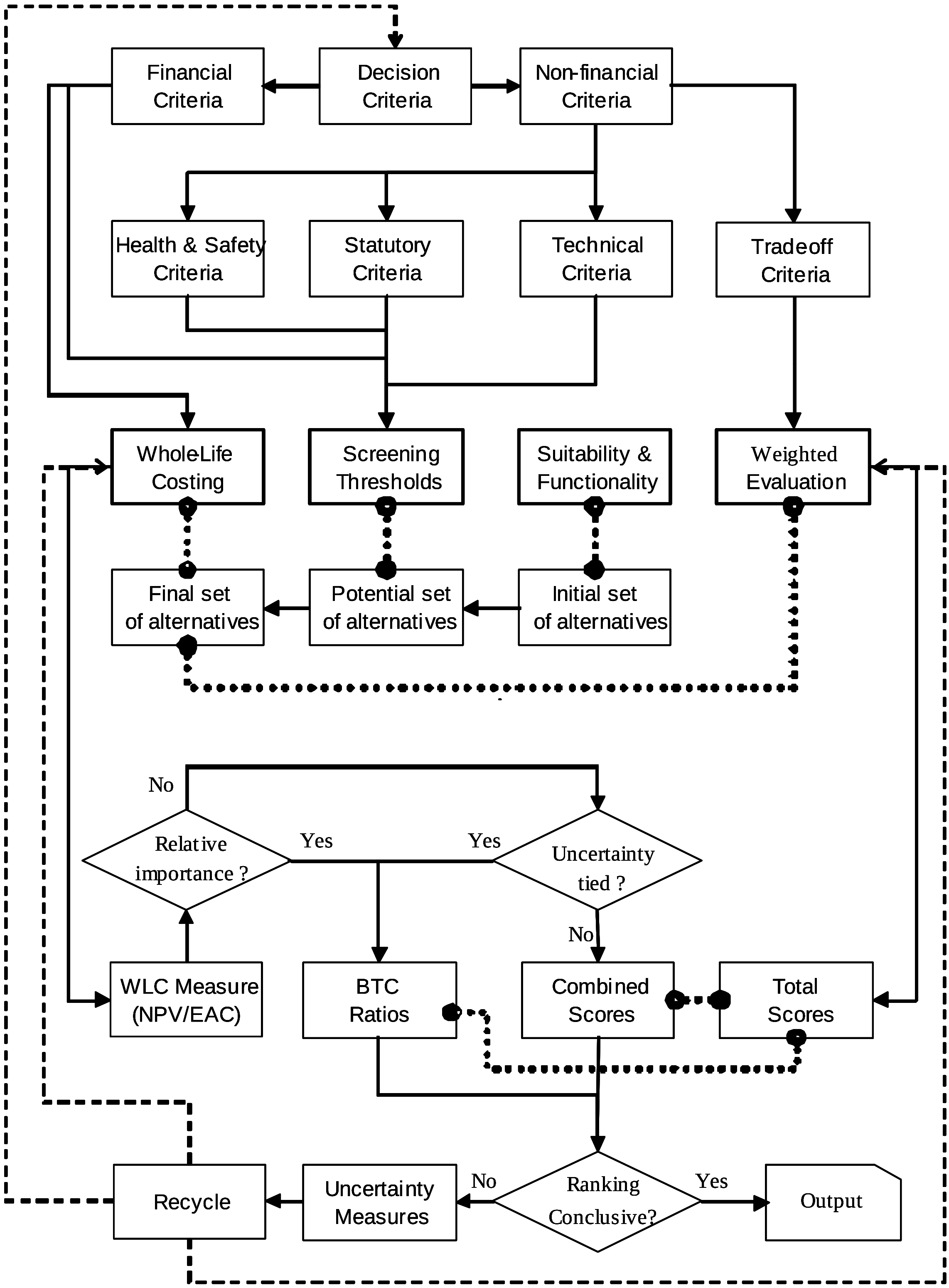


Figure 4: Schematic representation of the proposed algorithm.

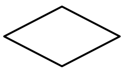
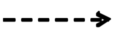
CONCLUSIONS AND THE WAY FORWARD

There has been little progress towards achieving an integrated approach that decomposes the process of selecting building elements into a flexible and logical series of activities that can be followed by decision makers. Crucial requirements for effective identification of decision criteria, generation of alternatives, and the decision-making process are identified. Then, a novel approach is outlined using simple process flow diagrams.

The proposed algorithm presents a methodological framework that utilizes desirable features of a number of existing well-developed methods. It employs a phased approach in the identification of decision criteria and alternatives where each phase results in a more specific list of criteria and alternatives. The main idea is to identify all available alternatives with the smallest set of key criteria. Alternatives that do not meet the statutory requirements and the minimum specification and performance requirements are excluded early in the process. Finally, the ideal alternative is selected based on a rigorous VFM analysis.

Future work includes implementing and testing the suggested framework as an integrated decision support system. First, four tools will be developed and tested individually to undertake the main phase of the proposed algorithm. Then, developed tools will be integrated through a user-friendly interface. The system will be tested in three phases. In the initial phase, the usability of the system's interface will be tested in a laboratory environment. A second phase will be to demonstrate the system to practitioners to get feedback on further refinements to the system's modeling capabilities. A third phase will be to implement the system in several corporate environments, and determine which refinements are needed to tailor it to specific organization use.

APPENDIX: LIST OF SYMBOLS

	Process.
	Decision.
	Output.
	Application/calculation loop.
	Recycle loop.

REFERENCES

Baas, S. and Kwakernaak, H. (1977) Rating and ranking of multiple aspect alternatives using fuzzy sets. *Automatica*, **13**(1), 47-58.

Belton, V., and Gear, T. (1983) On a short-coming of Saaty's method of analytic hierarchies, *Omega*, 228-230.

Bogenstatter, U. (2000) Prediction and optimization of life-cycle costs in early design, *Building Research & Information*, 28 (5/6), 376-386.

Braunschweig, T.; Janssen, W.; and Rieder, P. (2001) Identifying criteria for public agricultural research decisions, Research Policy, 30, 725–734

CIRIA (1999) Operation and maintenance manual for buildings - a guide to procurement and preparation. Ciria report C507.

Dale, S.J. (1993) Introduction to Life Cycle Costing. In Bull, J. W. (ed.) *Life Cycle Costing for Construction.* Blackie Academic & Professional, Glasgow, UK.

Dean, Y. (1996) Finishes. Fourth edition, Addison Wesley Longman Ltd, Harlow, England.

Ekel, P., Pedrycz, W. and Schinzinger, R. (1999) Methods of multicriteria decision making in fuzzy environment and their applications, *Annual Conference of the North American Fuzzy Information Processing Society - NAFIPS*, 10-12 June, New York, 625-629.

Griffin, J. J. (1993) Life cycle cost analysis: a decision aid. In Bull, J. W. (ed.), Life cycle costing for construction. Blackie Academic & Professional, Glasgow, UK.

Hwang, C.L. and Yoon, K. (1981) *Multiple attribute Decision making: methods and applications*. Springer-Verlag, New York.

Keeney, R.L., Raiffa, H. (1976) *Decisions with Multiple Objectives, Preferences and Value Tradeoffs*. Wiley, New York.

Kirk, S., J. and Dell'Isola, A. J. (1995) *Life Cycle Costing for Design Professionals.* McGrew-Hill Book Company, New York.

Kishk, M. (2001) An integrated fuzzy approach to whole-life costing based decision making. PhD Thesis. The Scott Sutherland School, The Robert Gordon University, Aberdeen, UK.

Kishk, M. (2002) Towards effective consideration of non-financial factors in the design and management of construction assets. Journal of Financial Management of Property and Construction, 7(3), 163-174.

Kishk M., Al-Hajj A., Pollock R., Aouad A., Bakis, N. and Sun, M. (2003) Whole-life costing in construction - a state of the art review. The RICS Research Paper Series, Vol. 4, No. 18.

Kishk, M.; Laing, R. and Pollock, R. (2004) A Methodological Framework for The Optimal Selection of Building Finishes. Salford Centre for Research & Innovation (SCRI) International Symposium, University of Salford, March 30th-31st 2004, 407-418.

Laing, R. A. (1999) Stone cleaning: a value assessment. PhD Thesis, School of Construction, Property and Surveying, The Robert Gordon University, Aberdeen.

Langston, C. A. and Ding, K. C. (2001) Sustainable Practices in the built environment, Second Edition, Oxford: Butterworth-Heinemann.

Lopes, M.D.S. and Flavell, R. (1998) Project appraisal – a framework to assess non-financial aspects of projects during the project life cycle. *International journal of project management*, **16**(4), 223-233.

Triantaphyllou, E. and Lin, C-T. (1996) Development and evaluation of five fuzzy multiattribute decision-making methods, *International Journal of Approximate Reasoning*, 14, 281-310.

Wilkinson, S. (1996) Barriers to LCC Use in the New Zeal and Construction Industry. Proceedings of the 7th International Symposium on Economic Management of Innovation, Productivity and Quality in Construction, Zagreb, 447-456.