Multi-Attribute Utility Theory for Contractor Pre-Qualification

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Abstract

Success of any construction project depends upon selecting capable and competent construction contractor, which is a major and crucial decision taken by construction clients.The present report analyses the criteria used to evaluate qualification of contractors. The bid price of construction works is the main criterion for evaluation of contractors. The lowest price often cannot guarantee commitments on quality and duration of a construction project. Therefore, when selecting a contractor, a client must not only compare bid prices but also set other criteria for evaluation of qualification and determine their weight. A contractor must be selected according to both quantitative and qualitative criteria, and bids should be compared. Only on the basis of quantitative and qualitative evaluation criteria and by comparing bids of contractors it is possible to select a qualified, competent and reliable contractor, to evaluate its qualification, economic and financial condition and technical capability and skills and to achieve relevant results in a construction project.

The present report provides an investigation of Indian companies, which analyses issues related to evaluation of construction contractors' qualification.
A systematic multi criteria decision analysis technique is described for contractor selection and bid evaluation based on utility theory and which permits different types of contractor capabilities to be evaluated.

Keywords - *criteria, bid price, quantitative and qualitative, reliable, multi criteria.*

I. INTRODUCTION

The construction industry plays a pivotal role in the socio-economic development of any nation. It is oftentimes regarded as the 'engine' that powers the pace of the socio-economic growth of the nation owning to its significant contribution to Gross Domestic Product (GDP).

The Indian construction industry comprises 250 firms in the corporate sector and in addition to these there is about1.3 lakh class-A contractors registered with different government construction bodies. Moreover there are several thousands of small contractors, who compete for small works, as sub-contractors of prime contractors. The unorganized and low skilled work force is the characteristic of the Indian construction industry. The complex and unique nature of construction demands the involvement of multiple participants in the delivery of a project. There have been extensive delays in the planned schedule, cost overruns, serious problems in quality and an increased number of claims and litigation. The construction industry has witnessed the failure of many contractors due to varying reasons such as financial problems, poor performance, or accidents arising from the lack of adequate safety consideration at worksites. As per 1992 survey report, around two-thirds of construction projects under implementation were observed to suffer significant time and cost over runs.

A construction project is generally carried out through a contract system- an agreement between the client and the construction agency. Based on the specific requirements of the project and the objectives of his organization, the client decides an appropriate tendering procedure and contractual arrangement to ensure that best value for money to the client, and fitness for purpose, i.e., satisfaction to the end-users are equally achieved in the absence of claims and counter-claims. As the contractor plays a pivotal role in any construction project, the crucial task of the selection by the client of the right contractor for the right project, therefore, constitutes the critical fulcrum upon which the overall success or otherwise of a construction project is precariously balanced.

An important characteristic of the construction industry is that the majority of contractors involved are small-scale firms. In many countries, there are thousands of contracting firms, which range from sole traders to large firms employing a workforce of several thousands. The existence of large number of contractors in a limited number of projects and uncertain construction industry environment results in intense competition between them. Among this large number of contractors, selecting the most appropriate is an important decision to be made by the client.

II. LITERATURE REVIEW

Multi-attribute utility theory is a method of establishing utility functions by mapping attributes (criteria) values into a constructed scale or mathematical form of preference. Utility is a measure of desirability or satisfaction and provides a uniform scale to compare and/or combine tangible and intangible criteria (Ang and Tang, 1984). A utility function is a mechanism used to quantity the preference of the decision maker by assigning a numerical index to varying levels of satisfaction of a criterion to the goal (Mustafa and Ryan, 1990).

Keeney and Wood (1977) employed MAUT to evaluate overall utility of five alternative water resources development plans for the Tisza river basin, Hungary.

Gershon and Duckstein (1983) used MAUT in addition to other methods for Santa Cruz river basin planning problem.

Hayashi (1998) presented a methodology for aiding agricultural decisions using multi-attribute value models with interval numbers for a case study in Japan.

Raju and Pillai (1999) applied MAUT and stochastic extension of PROMETHEE to rank irrigation subsystems of Sri Ram Sagar Project, Andhra Pradesh, India and selected one subsystem as the best.

Limon et al. (2003) presented MAUT methodology for a case study located in Northern Spain, Los Canales del Bajo Carrion, in the county of Palencia.

Raju et al. (2006) employed three phase methodology in multi objective framework involving formulation of payoff matrix, classification and ranking of irrigation planning strategies for a case study of Jayakwadi Irrigation Project, Maharashtra, India

Multi –Attribute Utility Theory (MAUT) is another MCDM method based on utility theory (Keeney and Raiffa, 1976; Goicoechea et al., 1982). The method takes into consideration the decision-makers preferences in the form of utility functions which are defined over a set of attributes (or criteria).
The following are the steps involved in MAUT for ranking alternatives:

1) Verification of preferential and utility independence conditions
2) Ranking of scaling constants of the criteria
3) Determination of indifference points
4) Derivation of single and multi-attribute utility functions
5) Determination of values of scaling constants
6) Ascertaining the attitude of the decision-maker based on the overall scaling constant
7) Ranking of the alternatives based on the utility values. Highest utility alternative is considered as best.

A. *Current Contractor Selection Practices*

A large number of procurement options are available to construction clients and five process elements are common to all types of procurement options. They are project packing, invitation, pre-qualification, short-listing and bid evaluation (Hautush, 1996).

Contractor selection is a decision-making process that occurs within the overall procurement strategy for the project. A contractor may be selected by competition or negotiation.

B. *Public And Private Sector Clients Contractor Selection Practices*

Public sector clients are generally bound, by legal regulations in many countries, to use an open competitive approach to avoid suspicion of favouritism and to demonstrate that the achievement of best value for public money has been ensured. Use of partnering through negotiation by some by some public bodies in the USA, for example, US Army Corps of Engineers (Weston and Gibson, 1993), has witnessed better project performance in terms of time, cost and quality.

However, private sector clients are not subject to any such regulation or accountability, and hence they may use more flexible alternative approaches available to them for the purpose. There may also be other routes to final contractor selection depending upon the objectives of the client organization and the specific requirements of the project under consideration. Whichever route is selected for the final selection, the prime aim is to select the right contractor who will give the client good value for money.

C. *Tender Evaluation Techniques*

The most difficult task faced by the construction clients in tender evaluation process is establishing the weight or relative importance of criteria, designing an appropriate scale of preference structure to be used by decision makers for assessing the capabilities of contractors, selecting a suitable technique to aggregate the ratings of decision makers on subset of criteria into an overall performance value, ranking of contractors in situations when one contractor scores better than others on a subset of criteria and but much worse on at least one criterion from the complementary subset of criteria.

Different researchers and construction practitioners have developed various methods or techniques for evaluating the tender proposals. For example, fuzzy set theory by Nguyen (1985): logistic regression technique by Russell and Jaselskis (1991); multiple regression technique by Holt (1995); multi attribute theory by Hatush and Skitmore (1998): analytic hierarchy process by Fong and Choi (2000), and Mahdi et al. (2002); a combination of utility function and social welfare function by Pongpeng and Liston (2003a).

D. Review of Current Contractor Selection

The current literature review has suggested some indication of paradigm shift in contractor selection practices, that is, from 'lowest price win' selection approach (e.g., Russell and Skibniewski, 1998; and Merna and Smith, 1990) to multiple criteria selection approach (e.g., Wong et al., 2001). Because of paradigm shifts in procurement methods, for example , moving more and/or different risks on to the contractors, deeper and wider evaluation of contractors' has become more important and necessary (kumaraswamy,1996), requiring consideration of broader sets of criteria and involvement of multiple decision makers. This has led many construction researches and practitioners to look for efficient and effective evaluation techniques for contractor selection which take into account simultaneous consideration of multiple criteria and multiple decision-making parties.

The review of literature revealed the existence of various criteria, methods and use for contractor prequalification and bid evaluation.

III. DEVELOPMENT OF CONTRACTOR SELECTION SYSTEM

Contractor selection is a complex decision-making process which requires simultaneous consideration of multiple decision criteria, usually conflicting and the decision-making is carried out by a panel of multiple decision-makers. Therefore, contractor selection is a multiple criteria decision-making problem involving human subjectivity, uncertainty, making the use of linguistic assessment of attributes more appropriate.

In this section, additive model of multi-attribute utility theory are discussed so that the results from the model can be compared to give a better conclusion to the contractor selection system.

A. Multi Attribute Utility Theory

Multi-Attribute Utility Theory is an evaluation scheme which is very popular by consumer organisations for evaluating products.

The purpose for using utility theory in decision making is to create a mathematical model to aid the process. It gives the decision maker the ability to quantify the desirability of certain alternatives.

It is been used as standard decision making tool in USA and many European countries. As it is multi criteria decision making method and its simplicity and easiness in formulation of model, it is used in contractor selection process for selecting optimal contractor among set of alternatives.

Utility theory is for design scenarios where uncertainty and risk are considered. The end result of using this method is a function which represents the designer's preferences, given a certain set of design attributes.

B. Selection of Attributes

Attributes are selected so that the designer's preference will be reflected in the attribute features. The range of the attribute must be selected so that it is useful, manageable, and should indicate the expected performance of the design.

When choosing the attributes, they must be:

1. Complete, such that important aspects are reflected in the design formulation
2. Operational, so that design decision analysis can be meaningfully implemented
3. Non-redundant, so there's no double counting
4. Minimal, for simplicity

C. Relative Rank Index Analysis

The data were analysed on the basis Relative Rank Index (RRI) technique. The RRI technique is very popular in the research fields of the built environment and the usage of this technique can be found in Assaf et al. (1996); Elinwa and Joshua (2001); Holt et al. (1994); Jennings and Holt (1998); Kometa et al. (1995); Mangitung and Emsley(2002); Shash 1993; Wong et al. (1999).

The RRI technique is used for comparison between the importance level of variables and derived from the Likert scales which represent the level of importance of variables chosen by respondents which need to be transformed into a Relative Rank Index that has a value of one or less. The RRI can be calculated using the following equation:

$$\text{RRI} = \frac{1}{nN}\left(\sum_{i=1}^{n} li\ xi\right)$$

Where RRI refers to Relative Rank Index
n- Maximum Likert scale value (here 5)
N-Total number of responses
i- 1, 2.....n
li =Likert scale (l1 is the least important and ln is the most important)
xi = the frequency of the ith response.

D. Development of Model

Decision analysis is concerned with situations in which decision-makers have to choose among several alternatives A1, A2,….,An, through the consideration of a common, but differently scored, set of attributes (criteria) for each alternative. Traditionally, the criteria scores/ weights are manipulated in such a way as to provide a consequence describable in terms of single criterion making it an easy task for the decision-maker to choose the most desirable alternative.

Profit maximisation has long been considered to be the prime objective of contract bidding strategies and has been a popular single criterion in use. In recent years, however, there has been a growing awareness that, whilst most decision-makers are interested in maximising profits, they are also concerned with other objectives such as corporate goodwill, market share, and future growth.

Selection of a construction contractor is also a decision characterised by multiple objectives. Owners want to minimise the likely cost of projects, but they also want contractors to maintain schedules as well as achieving acceptable quality standards.

IV. ADDITIVE MODEL

A utility function is a device which quantifies the preferences of a decision maker by assigning a numerical index to varying levels of satisfaction of a criterion.

A. Multi-Criteria Additive Utility function

All decisions involve choosing one, from several, alternatives. Typically, each alternative is assessed for desirability on a number of scored criteria. What connects the criteria scores with desirability is the utility function. The most common formulation of a multi-criteria utility function is the additive model.

Ui> Wj.Uij for all i,

Where

Ui is the overall utility value of alternative i,

uij is the utility value of the jth criterion for the ith alternative

Uij equals u(Xi), for $1 \geq i \geq n$ and $1 > j \geq m$

Xi equals (xij,) for 1> i>n and 1 > j>m. Xi designates a specific value of xij

n is the total number of criteria

m is the total number of alternatives

Wj is the relative weight of the jth criterion.

B. Selecting of Best Alternative

Each alternative is assessed by the sum product of utility value assigned to criteria scores (given by decision makers) to the respective indices priorities.

Ui= Σ(PI)j.Uij

Ui = overall utility value of alternative I

Uij = utility value of jth criterion for the ith alternative

(PI)j= indices priority of the jth criterion.

Optimal Contractor (best alternative) = highest overall utility value

C. Additive Model Summary

The advantage of the additive form is its simplicity. In order to determine the overall utility function for any alternative, a decision-maker need only determine n uni-dimensional utility functions for that alternative.

Multi-criteria utility theory generally combines the main advantages of simple scoring techniques and optimisation models. Further, in situations in which satisfaction is uncertain, utility functions have the property that expected utility can be used as a guide to rational decision-making.

V. CONCLUSIONS

Currently, bid price is the most important criterion in the selection of a contractor both in India and abroad. Although tender conditions list many other evaluation criteria, clients tend to select a contractor with the lowest bid price. Contractors should not be selected according to the lowest price, but it should be attributed to the highest weight.

There is a need for a contractor selection technique that is capable of considering multiple criteria. Multi criteria utility theory provides one such approach and is especially useful as it allows the treatment of both quantitative and qualitative criteria.

An additive model of utility technique is chosen for its simplicity, practicality and appropriateness in risky choice situations. The individual importance of each contractor criterion is specified using a weighting which also incorporates the risk of the decision-maker.

A Multiplicative model of utility technique in which Decision Maker has the key role in the whole problem formulation of multi attribute utility theory.

Multi criteria utility analysis is a technique for use in evaluation decisions where criteria are of different characteristics and it appears to be eminently suited to construction contractor selection.

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