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Selection of the most optimal contractor in Indian Construction Industry using Topsis and Extended Topsis model

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Abstract: *Contractor selection is one of the most important aspects in construction contract. This paper suggests importance of various multi criteria decision making models for contractor selection problem in Indian context. The study includes identifying the different criteria for bid evaluation and the means by which different decision making models may be used to evaluate the contractors with respect to each criterion. A general comparative study of topsis and extended topsis model has also been discussed. The research was conducted by sending a questionnaire to 300 respondents including public clients, private clients and contractors, and had an exceptionally high rate of response of 74%. From the survey results, the top 15 most preferred criterion from all the respondents has been selected and used to evaluate the contractors in the case study considered.*
Keywords– *Contractor, Extended Topsis, Multi criteria decision making model, Prequalification, Topsis*

I. Introduction

A construction project is generally carried out through a contract system –an agreement between the client and construction agency. The awarding of contracts to the right contractor is one of the most significant criteria in the successful delivery of construction projects. The failure of many construction projects may be caused due to various reasons like financial problems, poor performance, or accidents arising from the lack of adequate safety consideration at worksites (Singh and Tiong 2006) [1]. Hence there is a need to consider all these criteria in selecting the potential contractor and obtain a method that considers all the criteria attributing to the contractor selection. Contractor selection is a complicated decision making process involving the consideration of multiple selection criteria which are mostly subjective in nature and difficult to quantify (Singh and Tiong 2006) [1].

The use of the proposed contractor selection system has following benefits:

- It will help construction clients select the most appropriate contractor in a systematic, consistent and productive way;
- Therefore, the risk to the client of project failure resulting from awarding the contract to an in competent, incapable and inappropriate contractor will be greatly reduced;
- It will, therefore, help to some extent improve the performance of the construction industry.

II. Literature Review

Selection of the contractor for a construction project has long been based largely on bid price alone. Lately the lowest bid selection practice has been criticized because it involves high-risk exposure of the client, as , when faced with a shortage of work, the contractor desperately quote a low bid price simply to remain in business and expecting to compensate through claims.[4] Thus the selection based on the low price basis can be one of the reasons for project completion delays, poor quality and/or financial losses, etc. [3][5]. Topcu [2] states, that in seeking to minimize risk, the prequalification procedure is often chosen. Topcu [2] proposed a multi-attributes decision model based on time, price and quality attributes evaluation for eligible contractor selection. To set the proper contractor evaluation attributes, Hatush and Skitmore [3] suggested determining the client's needs and aims of a particular project. The proposed attributes involve price, time, quality parameters, uncertainty level, flexibility to make changes, the allocation of risks and the ability of a contractor to cope with the level of complexity that are involved.

In practice, the prequalification process has been performed by many different methods in different countries, such as: MAA (Multi-attribute analysis), MAUT (Multi- attribute utility theory), CA (Cluster analysis), MR (Multiple regression), FST (Fuzzy set theory), MDA (Multivariate discriminant analysis), etc. [6][7][9]. Recent years, a lot of experts and practitioners proposed many new methods which applied to contractors selection to reduce the risk of failure, such as: DEA (Data envelopment analysis), ANN (Artificial neural network), ANP (Analytic network process), CBR (Case-based reasoning), ES (Expert system), and so on.[8][10] All these methods have its own advantageous, but many of them also have some limitations, for example, the premise for use CBR is having many historical data, but in practice, it is hard to find the adequately data, so the CBR using is influenced.

III. Study Methodology

3.1 Multi criteria decision making methods

The Multiple Attribute Decision Making (MADM) techniques which are used in diverse fields such as engineering, economics, management science, transportation planning and etc, deal with candidate priority alternatives with respect to various attributes.

MCDM problems consist of multiple criteria, alternatives, and a DM or a group of decision makers. The methodology of multiple criteria decision making can be divided into three steps: (1) structuring the decision problem, (2) formulating a preference model, and (3) evaluating and comparing alternatives (Ozernoy 1992) [11]. A MCDM problem with both qualitative and quantitative criteria is usually structured in a hierarchy. The goal of a typical MCDM problem is usually to select a best alternative, *Ai* , from a set of *n* alternatives *A*= {*A*1 ,*A*2 ,...,*An*}.

The criteria are generally conflicting with each other or representing trade-offs. In most cases, there is no solution that satisfies all criteria simultaneously. In fact, criteria can be generally distinguished as "benefit" type, when the decision maker (DM) is interested in maximizing the evaluation of alternatives according to them, and "cost" type, when the DM wants to minimize them.

Before applying any MCDM methods, all the alternatives have to be evaluated according to each criterion. This requires the qualitative variables to be converted into crisp numbers and the criteria weights to be determined. In fact, the so-called decision matrix **A** (having *n* by *m* dimensions) may be assembled, assuming the generic element *aij* as the performance of the alternative *Ai* in respect to criterion *Cj*.

The evaluation of the alternatives according to the different criteria generally involves variables characterized by different units of measure. In these cases, a normalization of the involved variables may be needed.

In this paper we use the linguistics variables to evaluate the criteria that the given contractors satisfying and the importance weight of the criteria, then translate the linguistics variables into triangular fuzzy numbers, and using the TOPSIS method to calculate the fuzzy positive ideal solution and fuzzy negative ideal solution and the relative closeness to the ideal solution by every contractor, finally the most competent contractor is found.

3.2 TOPSIS method

TOPSIS (technique for order preference by similarity to an ideal solution) method is a popular approach to MADM and was first developed by Hwang and Yoon for solving a MADM problem. TOPSIS simultaneously considers the distances to the ideal solution and negative ideal solution regarding each alternative and selects the most relative closeness to the ideal solution as the best alternative. That is, the best alternative is the nearest one to the ideal solution and the farthest one from the negative ideal solution. A relative advantage of TOPSIS is the ability to identify the best alternative quickly.

Steps involved are:

a) First step – calculating the normalized matrix using the vector normalization, which is as follows:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x^2{}_{ij}}} \quad (j = 1, \dots n)$$

b) Second step – multiplication of normalized matrix elements with normalized weight coefficients w_j ; j = 1,2,..., n such as that: $\sum_{j=1}^{n} w_j = 1$ whereas the elements of the modified decision-making matrix are: $v_{ij} = w_j \,.\, r_{ij}$

c) Third step – determining the ideal and anti-ideal points in n-dimensional criteria space, so that ideal point is as follows:

$$A^* = \left(\max_i \ v_{ij} \ \ if \ j \in J\right), \left(\min_i \ v_{ij} \ if \ j \in \ J'\right) \ i = 1,2, \dots, m$$

$$A^* = \left(v_1^*, v_2^*, \dots, v_j^*, \dots v_n^*\right) - \text{ Ideal alternative coordinates}$$

$$A^- = \left(\min_i \ v_{ij} \ \ if \ j \in J\right), \left(\max_i \ v_{ij} \ if \ j \in \ J'\right) \ i = 1,2, \dots, m$$

$$A^- = \left(v_1^-, v_2^-, \dots, v_j^-, \dots v_n^-\right) - \text{ Anti Ideal alternative coordinates}$$

In this way, the coordinates of the ideal A^* and anti-ideal point A^- in the n-dimensional criteria space have been determined.

d) Fourth step – calculating of Euclidean distance Si^* of each alternative a_i, from the ideal point and S_i^- of each alternative a_i from the anti-ideal point A^- :

$$S_i^* = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^*)^2}, \quad i = 1,...,m$$

.

-Euclidean distance of the i^n alternative from the ideal point;

$$S_i^- = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^-)^2}, \; i = 1,... m$$

-Euclidean distance of the i^n alternative from the anti-ideal point.
e) Fifth step – calculating the relative similarity of the alternatives from the ideal and anti-ideal points which is done in the following manner:

$$C_i = \frac{S_i^-}{S_i^* + S_i^-}; 0 < C_i \leq 1; i = 1, ..., n$$

If C_i =1 then $a_i = A^*$ and if C_i =0, then $a_i = A^-$. Therefore, the conclusion is that a_i is closer to A^* if the C_i is closer to value 1.
f) Sixth step – setting up the rank according to C_i , meaning that the bigger C_i is - the better the alternative would be.

3.3 Extended Topsis Method

The basic principle of the Topsis method proposed by Hwang and Yoon is that the chosen points should have the ”shortest” distance from the positive ideal and the ”farthest” distance from the negative ideal solution. In their TOPSIS model, the measurement of weights and qualitative attributes did not consider the uncertainty associated with the mapping of human perception to a number. The concept of applying fuzzy numbers to TOPSIS was first suggested by Negi and Chen and Hwang[12], but their fuzzy TOPSIS algorithms are incomplete. The main steps of multiple criteria-attribute (complex) decision-making are as following:

a) Establishing system evaluation criteria that relate system capabilities to goals.
b) Developing alternative systems for attaining the goals. (Generating alternative)
c) Evaluating alternative in terms of criteria.(the values of the criterion functions)
d) Applying a normative multi-criteria analysis method.
e) Accepting one point as ”optimal”.
f) If the final solution is not accepted, gather new information and go into the next iteration of multi-criteria optimization.

Steps (a) and (e) are performed at the upper level, where decision makers have the central role, and the other are mostly engineering tasks. For steps (d) and (a) decision maker should express her/his idea about importance of criteria to determining weights of criteria. These weights do not have clear economic significance, but they match model with actual concepts of decision making. By considering this fact that in many cases determining precisely the exact value of the attribute respect to criteria is difficult, their values are considered as fuzzy data. Therefore the concept of TOPSIS is extended to solving problems under uncertainty.

The procedure of evaluating the alternatives is similar to that of TOPSIS method as described above, but here the importance weight of criteria is given in terms of linguistic variables. The linguistic variables used here can be expressed in triangular fuzzy numbers as given in Table 1 and 2 below:

Table 1: Fuzzy numbers for linguistic variables for the important weight of each criterion

Linguistic variables	Fuzzy number
VH(very high)	(0.75,1.00,1.00)
H (high)	(0.50,0.75,1.00)
A(average)	(0.25,0.50,0.75)
L(low)	(0.00,0.25,0.50)
VL(very low)	(0.00,0.00,0.25

Table 2: Fuzzy numbers for linguistic variables for the contractors satisfying each criteria

Linguistic variables	Fuzzy number
VG (very good)	(0.75,1.00,1.00)
G (good)	(0.50,0.75,1.00)
A(average)	(0.25,0.50,0.75)
P (poor)	(0.00,0.25,0.50)
VP (very poor)	(0.00,0.00,0.25)

3.4 The proposed Algorithmic Method

Step1: Construct the fuzzy linguistic decision matrix $A = (a_{ij})_{m\,x\,n}$

$$A = \begin{pmatrix} x_{11}, x_{12}, \dots, x_{1n} \\ x_{21}, x_{22}, \dots, x_{2n} \\ \dots \dots \dots \dots \dots \\ \dots \dots \dots \dots \dots \\ x_{m1}, x_{m2}, \dots, x_{mn} \end{pmatrix}$$

Where *A*1, *A*2,.., *Am* are the alternatives, *c*1, *c*2,..,*cn* are the criteria, *xij* denotes the evaluation of the alternative *Ai* using linguistic variables according to criteria *cj*. The weight vector *W*=(*w*1, *w*2,.., *w*n) included the individual weight *wj* for each criteria *cj*.

The normalization process is not necessary, due to the fact that all the attribute values are assessed using the same set of linguistic variables. In other words, the fuzzy linguistic decision matrix equals the normalized matrix.

Step 2: Calculate the fuzzy weighted decision matrix

In this paper we use several decision makers to evaluate the contractors' abilities and the importance weight of the criteria, here we assume the number of decision makers is *h*. In order to reduce the influence of the decision makers' subjective estimation to the result, we use the fuzzy average operation to balance the decision makers evaluation, so the average evaluation value of the decision makers for the contractors according to each criterion is calculated by:

$$x_{ij} = \left(\frac{1}{h}\sum_{k=1}^{h} x_{ij}^{L}, \frac{1}{h}\sum_{k=1}^{h} x_{ij}^{M}, \frac{1}{h}\sum_{k=1}^{h} x_{ij}^{U}\right)$$

And the average evaluation value of the decision makers for the given criteria is calculated by:

$$w_j = \left(\frac{1}{h}\sum_{k=1}^{h} w_j^{L}, \frac{1}{h}\sum_{k=1}^{h} w_j^{M}, \frac{1}{h}\sum_{k=1}^{h} w_j^{U}\right)$$

After consider the weight of each criterion, we calculate fuzzy weighted decision matrix $B = (y_{ij})_{m\,x\,n}$ with *i*=1, ..,*m* and *j*=1,... ,*n* by multiplying the averaged decision matrix by the weights matrix. The fuzzy weighted decision matrix is calculated as:

$y_{ij} = x_{ij} \times w_j$, with *i*= 1,...,*m* and *j*= 1,...,*n*

Step 3: Calculate the distance between the fuzzy evaluating value and FPIS and FNIS

The use of numerical values in the ranking of alternatives might have limitations in the uncertainty environment. So extension of TOPSIS was developed to solve problems of decision making with uncertain data resulting in fuzzy TOPSIS. Here we define the fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS) in the fuzzy environment.

FPIS $A^{*} = \{\max y_{ij} \quad , if\ j \in J, i = 1, \ldots, m\}$
FPIS $A^{-} = \{\min y_{ij} \quad , if\ j \in J, i = 1, \ldots, m\}$

Where J={j=1,..,n}, while FPIS and FNIS can be expressed as:
$A^{*} = (y_1^{*}, y_2^{*}, \ldots, y_n^{*})$
$A^{-} = (y_1^{-}, y_2^{-}, \ldots, y_n^{-})$
Step 4: Calculate the separation measure of every alternative from FPIS and FNIS
According to the Euclidean distance method can be used to aggregate the distance of FPIS and FNIS to all criteria for every alternative.

$$d(a,b) = \sqrt{\frac{[(a^L - b^L)^2 + (a^M - b^M)^2 + (a^U - b^U)^2]}{3}}$$

The separation of each point from positive and negative ideal solution calculated by using:

$$S_i^{*} = \sqrt{\sum_{j=1}^{k} d(y_{ij}, y_j^{*})^2}$$

$$S_i^{-} = \sqrt{\sum_{j=1}^{k} d(y_{ij}, y_j^{-})^2}$$

here i = 1, ...,m.

Step 5: Calculate the relative closeness to the ideal solution by every alternative
The relative closeness of the alternative *Ai* with respect to *A** is defined as:

$$Q_i = \frac{S_i^{-}}{S_i^{*} + S_i^{-}} , i = 1, \ldots, m$$

Where $0 \leq Q_i \leq 1$

Step 6: Rank the alternatives
A set of alternatives can now be ranked according to the descending order of Q_i and the one with the maximum value of Q_i is the best.

IV. Data Collection

Obtaining sound data is perhaps the most important and demanding aspect of the research process. Data can be obtained in a variety of ways, in different settings-field or laboratory and from different sources-primary or secondary. The methods include interview, observation, questionnaire survey, unobtrusive methods, documents and historical data. The use of an appropriate data collection method greatly enhances the robustness of data and thus the value of the research. First of all, preliminary interviews were conducted with the experts in contractor procurement in order to filter out irrelevant criteria from the preliminary set of decision criteria and sub-criteria extracted from literature review.

4.1 Preliminary study

An initial list of 155 criteria, apart from tender price, is selected on the basis of popularity of their use in the context of UK, USA, Hong Kong, Australia, Singapore and Indian Construction industries(Russellet al ,1992; kumaraswamy,1996; Hatush and Skitmore, 1997[3]; Palaneeswaran and Kumaraswamy, 2001;D.Singh and Robert L.K Tiong, 2005). In order to identify the criteria that would be significant for contractor procurement in Indian context, several experienced construction practitioners from public agencies and consulting firms were contacted to elicit their opinions on the relevance of these criteria in contractor evaluation process. Ten professionals who have been associated with contractor selection and tender evaluation exercise or contract management participated in the preliminary interviews. Based on the comprehensive and valuable input from those experts, 70 evaluation criteria were selected to be included in the final version of the questionnaire.

4.2 Questionnaire Survey

Questionnaires are an efficient data collection mechanism in situations what is required and how to measure the variables of interest is exactly known. A structured questionnaire is a pre-formulated written set of questions to which respondents record their answers, usually within rather closely defined alternatives. While designing the questionnaire care is taken to enable the respondents understand the questions without difficulty and to provide a meaningful response thereby improving the response rate and increasing the chance of getting more conclusive inferences during data mining process.

The purpose of the questionnaire survey is to elicit the information regarding the selection criteria used for tender evaluation and the criteria evaluation methods used by construction clients for assessing the capabilities of the contractors so that the relative importance of CSC to be used in the proposed contractor selection system can be established. The relevant and important CSC, in addition to tender price, selected from preliminary round of interviews are shown in the Table 3

Table 3. Main Criteria for contractor selection

Code	**Main Criteria**
A	Contracting Company's attributes
B	Experience record
C	Past performance of the contractor
D	Financial capability of the contractor
E	Performance potential of the contractor
F	Project specific criteria

A measurement scale is essential for collecting the opinions, of respondents meaningfully, on the importance of the criteria. Therefore, a six-point Likert scale (0-5) is used for recording the perceptions of respondents. Respondents are asked to indicate the level of importance of criteria in assessing the capabilities of the contractor on the linguistic scale, where IR means the criterion is Irrelevant, VLI means Very Low Importance, LI means Low Importance, MI means Medium Importance, I means Important and VI means Very important. These linguistic terms are converted into numerical values such that IR (0), VLI (1), LI (2), MI (3), I (4) and VI (5) in order to generate a quantified measure of the criteria to be used for statistical analysis.

4.3 Data Analysis

The data were analysed on the basis Relative Rank Index (RRI) or Relative Importance Index (RII) 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 levels of variables and derived from the Likert scales. These represent the level of importance of variables chosen by respondents which need to be transformed into a Relative Rank Index (RRI) which has a value of one or less. The RRI can be calculated using the following equation:

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

Where RRI refers to Relative Rank Index
n = Maximum Likert scale value (here 5)
N = Total number of responses
i = 1, 2..., n
l_i =Likert scale (l_1 is the least important and l_n is the most important)
x_i = the frequency of the i^{th} response.

Table 4. RRI values obtained

Code	Criteria	RRI
A1	Age and registration of contractor's firm or company	0.808
B2	Experience of working on similar projects	0.892
B6	Type and size of past projects	0.820
C2	Work quality in completed projects (i.e. third party quality certification and incentives awarded)	0.832
C3	Adherence to time schedule in past works	0.866
C12	Blacklisting in past projects	0.913
C13	Quality of service during warranty	0.837
D1	Current commitments	0.808
D6	Turnover	0.848
E5	Availability of plant and equipment resources	0.824
E6	Present workload and capability to support the current project	0.833
E7	Quality control and assurance program	0.852
E8	Specialised knowledge of particular construction method	0.814
F2	Specified project time schedule	0.859
F4	Qualification and experience of professional and technical staff	0.830

The questionnaire survey included three groups of respondents including Public clients, private clients and Contractors or construction firms. The construction firms are also considered in the survey with the objective to draw the consensus, from contractors' standpoints, on the importance of those evaluation criteria in assessing the capabilities of the contractors to deliver the project successfully in terms of time, cost and quality standards so that the best value for money is achieved.

As many as 222 respondents' views are collected regarding the contractor selection criteria preferences. The respondents include 93 public clients, 63 private clients and 66 contractors who are having enough experience in the construction industry. The private clients include the developers, architects and the consultants so as to realistic results.

Relative Rank Index (RRI) values of different criteria obtained from all the respondents' views are computed. The ranking of criteria is carried out on the basis of their corresponding RRI values, that is higher the RRI value the higher the rank and vice-versa. The results obtained shows that there is slight difference in views of public and private sector and between that of clients and contractors as well.

From the results obtained, B2: experience of working on similar projects is assigned the highest importance value by public sector clients, E3: Qualification and experience of technical staff is assigned highest importance value by private sector clients while C12: Black listing in past projects is found important from the view point of the contractors. A5: Company's trade union record is observed to be of least importance from all the three respondent groups.

In the present study, the criteria having 80% and more of RRI value (>0.80), calculated from the perceptions of 3 groups of respondents taken together, are considered for the contractor evaluation process.

4.4 Computational procedure for selecting a contractor

A case study on "Construction of a multi-storeyed building is considered to illustrate the above methodology to contractor selection decision scenario. The estimated contract value is more than Rs 37 crores. Period of completion of work is given as 25 months. Four contractors participated in the tendering process. The contractors' data as obtained from the technical bids scrutiny note is as shown in the table 5 and table 5.1.

In the discussed problem there are four contractors: A,B,C, and D. The decisions are taken by a committee of three members DM 1, DM 2 and DM 3; the weightage of these committee members/decision makers varies based on various criteria like years of experience, technical expertise etc.

Table 5. Contractor's Data

S.No.	Contractor A	Contractor B	Contractor C	Contractor D
1	16 yrs in construction	16yrs in construction	17 yrs in construction	14yrs of construction
2	5 similar projects	3 similar projects	4 similar projects	4 similar projects
3	Not Furnished	ISO 9002 : 94	ISO 9002	ISO 9001: 2000
4	Medium Importance to Health and safety	Moderate Importance to Health and safety	Importance to Health and safety	Medium Importance to Health and safety
5	75% works completed in time	83% works completed in time	90% works completed in time	95% works completed in time
6	3 Debarment from past projects	2 Debarment from past projects	1 Debarment from past projects	1 Debarment from past projects
7	Arbitration- NO	NO	NO	YES
8	1. IT park - 72 cr. 2.Corporate Office Building - 43.5 cr 3.Residential Tower - 23.8 cr	1.Software Building - 47 cr 2. Residential Building- 23 cr 3.Commercial Building - 27 cr	1.Transit sale - 86 cr 2.Maharashtra State Board - 100 cr 3.Construction of Hospital - 19.7 cr	1. Software Building - 105.6 cr 2. Accommodation Building-29.92 cr 3.Software Building - 106.55 cr
9	Average organization	Good organization	Good organization	Good organization
10	2002-03 - 129 crore 2003-04 - 220 crore 2004-05 - 355 crore	2002-03 - 210.82 crore 2003-04 - 185.73 crore 2004-05 - 172.56 crore	2002-03 - 11.45 crore 2003-04 - 44.70 crore 2004-05 - 43.74 crore	2002-03 - 101.69 crore 2003-04 - 125.62 crore 2004-05 - 159.60 crore
11	Average Quality	Average Quality	QA/QC	QA/QC program
12	Testing equipment not available for Quality assurance	Testing equipment available for Quality	Testing equipment available for Quality	Testing equipment available for Quality
13	130 labourers	145 labourers	160 labourers	150 labourers

Table 5.1. Contractor's Data – Plant & Equipment

	Contractor A			Contractor B			Contractor C			Contractor D		
	Plant	**Capacity**	**No.**	**Plant**	**Capacity**	**No.**	**Plant**	**Capacity**	**No.**	**Plant**	**Capacity**	**No.**
Plant & Equipments	Batching Plant	32 Cum /Hr	6	Batching Plant	30 Cum /hr.	8	Batching plant	8-30 Cum /hr.	12	Batching plant	20 - 30 Cum /hr.	12
	Concrete Mixers	6 Cum /Hr	10	Concrete Mixers	10 / 7 , 14 / 10	87	Transit Mixers	6 Cum	35	Transit Mixers	-	26
	Concrete Pumps	20 Cum /Hr	8	Concrete Pumps	35 Cum /hr.	6	Concrete Pump	46 Cum /hr.	8	Concrete Pump	20 Cum /hr.	6
	Tower Cranes	36m High	2	Transit Mixers	4 Cum / 6 Cum	10	Concrete Mixers	10 / 7 Cft	6	Concrete Mixers	3 Cum	72
	Welding Plant	6 Joints / Hr	4	Pick & Carry Crane	8 MT	4	JCB	1.2/8MT	3	Mobile tower crane JCB	-	4
				Pick & Carry Crane	10 MT	1	Tower Crane	8 MT	3	Tower Crane	10 MT	3

V. Results

5.1 Validation of Topsis method

Table 6.1: Decision matrix for main criteria

CRITERIA	PRIORITY	NORMALISED VALUE
A	3	0.079
B	9	0.237
C	7	0.184
D	8	0.210
E	6	0.158
F	5	0.132

Table 6.2: Decision Matrix

	A	B	C	D
A1	7	7	7	5
B2	9	5	7	5
B6	3	5	7	7
C2	5	5	5	5
C3	5	7	9	9
C12	9	9	9	5
C13	5	5	5	5
D1	7	7	5	9
D6	7	5	3	7
E5	7	9	9	9
E6	5	5	5	5
E7	3	9	9	7
E8	5	5	5	5
F2	5	5	5	5
F4	5	7	5	7

Table 6.3: Normalised weighted decision matrix

	A	B	C	D
A1	0.0422	0.042	0.0422	0.03
B2	0.0828	0.046	0.0644	0.046
B6	0.0296	0.049	0.0692	0.069
C2	0.0222	0.022	0.0222	0.022
C3	0.015	0.021	0.0271	0.027
C12	0.0268	0.027	0.0268	0.015
C13	0.0223	0.022	0.0223	0.022
D1	0.0502	0.05	0.0359	0.065
D6	0.0655	0.047	0.0281	0.066
E5	0.0161	0.021	0.0206	0.021
E6	0.0198	0.02	0.0198	0.02
E7	0.0082	0.025	0.0246	0.019
E8	0.0194	0.019	0.0194	0.019
F2	0.0336	0.034	0.0336	0.034

F4	0.0267	0.037	0.0267	0.037

Now, we compute the amount of ideal and anti ideal alternatives and find the separation measures of those from every alternative and then the rank of contractor is determined.

Table 6.4: Rank of contractors

A	B	C	D
0.5422	0.458	0.4974	0.613
II	IV	III	I

5.2 Validation of Extended Topsis method

Table 7.1: The evaluation of importance of criteria by decision makers

	DM1	DM2	DM3	Average value
A1	L	L	A	(0.08,0.33,0.58)
B1	H	A	A	(0.33,0.58,0.83)
B2	H	H	VH	(0.58,0.83,1)
B6	VH	H	VH	(0.67,0.92,1)
C2	H	H	H	(0.5,0.75,1)
C3	H	H	A	(0.42,0.67,0.92)
C12	H	H	A	(0.42,0.67,0.92)
D3	H	H	VH	(0.58,0.83,1)
D6	H	VH	VH	(0.67,0.92,1)
E5	H	A	A	(0.33,0.58,0.83)
E6	H	A	A	(0.33,0.58,0.83)
E7	VH	H	H	(0.58,0.83,1)
E8	A	A	H	(0.33,0.58,0.83)
F2	L	L	A	(0.08,0.33,0.58)
F4	A	L	A	(0.17,0.42,0.67)

Table 7.2: The evaluation of alternatives by decision makers

	DM1				**DM2**				**DM3**			
	A	**B**	**C**	**D**	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**
A1	G	G	G	A	G	G	A	A	G	G	A	A
B1	G	G	G	A	G	G	A	A	G	G	A	A
B2	A	G	G	G	A	A	A	G	A	A	G	G
B6	A	G	G	G	A	A	A	G	P	A	A	G
C2	G	A	G	A	A	A	A	A	G	G	G	A
C3	A	A	A	A	A	A	A	A	A	A	A	A
C12	A	A	A	P	A	A	A	P	A	A	A	P
D3	VG	G	A	G	G	G	A	G	VG	G	G	G
D6	VG	A	P	G	G	A	A	G	VG	G	G	G
E5	G	A	A	G	G	A	A	G	G	G	G	G
E6	A	G	P	G	G	G	A	G	G	G	A	G
E7	P	A	G	A	A	A	G	A	A	A	G	A

E8	A	A	A	A	A	A	A	A	A	A	A	A
F2	A	A	A	A	A	A	A	A	A	A	A	A
F4	A	A	A	A	A	A	A	A	A	A	A	A

Table 7.3: The fuzzy weighted value of alternatives

	A	**B**	**C**	**D**
A1	(0.04,0.25,0.58)	(0.042,0.25,0.583)	(0.028,0.194,0.49)	(0.021,0.167,0.438)
B1	(0.17,0.438,0.83)	(0.167,0.438,0.833)	(0.111,0.34,0.69)	(0.083,0.292,0.625)
B2	(0.15,0.417,0.75)	(0.194,0.486,0.833)	(0.243,0.556,0.92)	(0.292,0.625,1)
B6	(0.11,0.382,0.67)	(0.222,0.535,0.833)	(0.222,0.535,0.83)	(0.333,0.688,1)
C2	(0.21,0.5,0.92)	(0.208,0.5,0.917)	(0.208,0.5,0.92)	(0.125,0.375,0.75)
C3	(0.1,0.333,0.69)	(0.104,0.333,0.688)	(0.104,0.333,0.69)	(0.104,0.333,0.688)
C12	(0.1,0.333,0.69)	(0.104,0.333,0.688)	(0.104,0.333,0.69)	(0,0.167,0.458)
D3	(0.39,0.764,1)	(0.292,0.625,1)	(0.194,0.486,0.83)	(0.292,0.625,1)
D6	(0.44,0.84,1)	(0.222,0.535,0.833)	(0.167,0.458,0.75)	(0.333,0.688,1)
E5	(0.17,0.438,0.83)	(0.111,0.34,0.694)	(0.111,0.34,0.69)	(0.167,0.438,0.833)
E6	(0.14,0.389,0.76)	(0.167,0.438,0.833)	(0.056,0.243,0.56)	(0.167,0.438,0.833)
E7	(0.1,0.347,0.67)	(0.146,0.417,0.75)	(0.292,0.625,1)	(0.146,0.417,0.75)
E8	(0.08,0.292,0.63)	(0.083,0.292,0.625)	(0.083,0.292,0.625)	(0.083,0.292,0.625)
F2	(0.02,0.167,0.44)	(0.021,0.167,0.438)	(0.021,0.167,0.44)	(0.021,0.167,0.438)
F4	(0.04,0.208,0.5)	(0.042,0.208,0.5)	(0.042,0.208,0.5)	(0.042,0.208,0.5)

Next the FPIS and FNIS are found out and the distance of FPIS and FNIS to all the criteria for every alternative is found out and then the rank of contractor is determined and tabulated in table 7.4.

Table 7.4: Relative closeness to the ideal solution by every alternative

	A	**B**	**C**	**D**
d+	0.45	0.40	0.49	0.38
d-	0.51	0.422	0.41	0.501
Q*	0.53	0.514	0.46	0.569
RANK	**II**	**III**	**IV**	**I**

From the overall priority values obtained, contractor D is found to be best choice from the decision makers' preferences.

Table 8. Comparison of Results**:**

Models	Rank for the Contractor Rank for the contractor			
	Contractor A Contractor A	Contractor B	Contractor C	Contractor D
TOPSIS	II	IV	III	I
Extended Topsis	II	III	IV	I

VI. Discussions and Conclusion

We can see that the two multi criteria decision making methods used here are an effective tool for contractor selection problem. They aid us in selecting the most competent contractor from a set of contractors and thus the right contractor for the right project can be selected very efficiently.

Topsis method has got relative easiness when compared with the extended model, but since the measurement of weights and qualitative attributes did not consider the uncertainty associated with the mapping of human perception to a number, the concept of applying fuzzy numbers to TOPSIS can give better results. Table 9 below shows a general comparative study between the models:

Table 9. General Comparison of models

EVALUATION TECHNIQUES	TOPSIS	EXTENDED FUZZY TOPSIS
Support for qualitative parameters	Yes	Yes
Support for qualitative parameters	Yes	Yes
If the number of alternatives to be evaluated increases	Rating of each alternative withregard to each evaluation criterion must be done beforecalculating final score	Rating of each alternative with regard to each evaluation criterion must be done before calculating final score
Support for knowledge / Experience	No	No

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