An Approach for Ready Mixed Concrete Selection For Construction Companies through Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) Technique

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Abstract-Ready Mix Concrete (RMC) industry is continuously growing all over the world and India is not an exception to it. The pace of mechanization in the past was very slow due to the availability of cheap and abundant labor, lack of capital investment and the highly fragmented nature of the construction sector. Multi-criteria decision making for evaluation of Ready Mixed Concreteby implementing Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method is simple to understand and permits the pursuit of best alternative criterion depicted in a simple mathematical calculation. Due to this, decision making for selection of suitable Ready Mixed Concrete is of special importance. The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was first developed by Yoon and Hwang. For a Ready Mixed Concrete selection different important criteria are takeninto account. These criteria have different weights by different experts. Using these weights provides the rank to every Ready Mixed Concrete with the help of a Technique for Order Preference by Similarity to Ideal Solution (TOPSIS).

Keywords: Ready Mixed Concrete, Mechanization,Multi criteria decision making, Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method, decision making

I.INTRODUCTION

Agarwal et al. [2]review sixty-eight articles from 2000 to 2011 to find out the most prominent MCDM methodology followed by the researchers for supplier evaluation and selection.They report the distribution of MCDM methods used in these articles by DEA 30%, mathematical programming models 17%, Analytic Hierarchy Process (AHP) 15%, CBR 11%, Analytic Network Process (ANP) 5%, fuzzy set theory 10%, simple multi-attribute rating technique (SMART) 3%, genetic algorithm (GA) 2%, and criteria based decision making methods such as ELECTRE and PROMETHEE 7%.

Chen et al.Use the fuzzy TOPSIS method for supplier selection problem. Chen uses DEA technique to screen potential suppliers and then TOPSIS method to rank the candidate suppliers [6, 7, and 4].

Ready Mixed Concrete Selection process is one of the most significant variables, which has a direct impact on the performance of the Construction Industry.

Manuscript received October, 2013.

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As the Construction Industry becomes more and more dependent on ReadyMixed Concrete, the direct and indirect consequences of poor decision making will become more critical. The nature of this decision is usually complex and unstructured. On the other hand, Ready Mixed Concrete Selection decision-making problem involves trade-offs among multiple criteria that involve both quantitative and qualitative factors, which may also be conflicting.With the help of going over expertise of experts and their relevant specialized literature, researchers can recognize variables and effective criteria in Ready Mixed Concrete Selection. The main and important criteria of Ready Mixed Concrete have been extracted by expert judgment. Thereafter, this concept will evaluate and determine the weight of each Ready Mixed Concrete and finally, by implementing TOPSIS method, the rank of Ready Mixed Concrete is determined.TOPSIS has been a favorable technique for solving multi criteria problems. This is mainly for two reasons, 1. - Its concept is reasonable and easy to understand, and 2. - In comparison with other MCDM methods, like AHP, it requires less computational effort, and therefore can be applied easily. TOPSIS is based on the concept that the optimal alternative should have the shortest distance from the positive ideal solution (PIS) and the farthest distance from the negative ideal solution (NIS). TOPSIS method is powerful decision making processes which help people to set priorities on parameters that are to be considered by reducing complex decision to a series of one-to-one comparisons, thereby synthesizing the result [5].

II.LITERATURE REVIEW

Ready Mixed Concrete was first patented in Germany in 1903, but a means of transporting was not sufficiently developed by then to enable the concept to be utilized commercially. The first commercial delivery of Ready Mixed Concrete was made in Baltimore, USA in 1913 and first revolving-drum-type transit mixer, of a much smaller capacity than those available today, was born in 1926. In 1920s and 1930s, Ready Mixed Concrete was introduced in some European countries.

Ready Mixed Concrete plants arrived in India in the early 1950s, but their use was restricted to only major construction projects such as dams. Later Ready Mixed Concrete was also used for other projects such as construction of long-span bridges, industrial complexes, etc. There were, however, captive plants which formed an integral part of the construction project. It was during 1970s when the Indian construction industry spread its tentacles overseas, particularly in the Gulf region, that an awareness of Ready Mixed Concrete was created among Indian engineers, contractors and builders.

Indian contractors in their works abroad started using Ready Mixed Concrete plants of 15 to 60 m3/h and some of these plants were brought to India in 1980s. Currently there are approx. 30 Ready Mixed Concrete Plants operating in different parts of Gujarat.

The Ready Mixed Concrete business in India is in its infancy. For example, 70% of Cement produced in a developed country like Japan. Here in India, Ready Mixed Concrete business uses around 2% of total cement production.

Ready Mixed Concrete (RMC) is a specialized material in which cement, aggregate, and other ingredients are weight batched at a plant in a central or a truck mixer before delivery to the construction site in a condition ready for placing by the customer. RMC is manufactured at a place away from the construction site, the two locations being linked by a transport operation.

Basic requirement for growth of the industry: - Government bodies, private builders, architects/engineers, contractors and individuals are to be made fully aware about the advantages of using Ready Mixed Concrete. Government bodies / consultants to include Ready Mixed Concrete as mandatory in their specification for execution [3].

III. PROPOSED METHODOLOGY

The proposed methodology for Ready Mixed Concrete selection problem, composed of TOPSIS method, consists of three steps:

1. Identify the criteria to be used in the model;
2. Weight the criteria by using expert views;
3. Evaluation of alternatives with TOPSIS and determination of the final rank.

In the first Step, with the help of going over expertise of experts and their relevant specialized literature, researchers try to recognize variables and effective criteria in the Ready Mixed Concrete selection and the criteria which will be used in their evaluation is extracted. Thereafter, the list of qualified Ready Mixed Concrete are determined and in the last stage of the first step, the decision criteria are approved by decision-making team. After the approval of decision criteria, weights are assignedto them by organizing experts' sessions in the second step. In the last stage of this step, calculated weight of the criteria are approved by the decision making team. Finally, ranks are determined, using TOPSIS method in the third step. Schematic diagram of the proposed model for Ready Mixed Concrete is provided in Figure 1.[11]

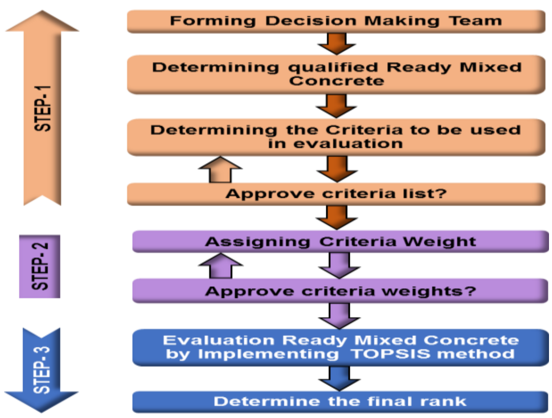

Figure: 1 Schematic diagram of the proposed methodology

The Technique For Order Preference By Similarity To Ideal Solution (Topsis) Method

TOPSIS (for the Technique for Order Preference by Similarity to Ideal Solution) was developed by Yoon and Hwang [1980] as an alternative to the ELECTRE method and can be considered as one of its most widely accepted variants[1, 9, 8, and 14].

The basic concept of this method is that the selected alternative should have the shortest distance from the ideal solution and the farthest distance from the negative-ideal solution in a geometrical sense. The method evaluates the decision matrix, which refers to n alternatives that are evaluated in terms of m criteria. The only subjective input needed is relative weights of attributes [10].

Application of this method (Behm, 2005) makes it necessary for the fact that the efficiency function of each solution criterion increases or decreases monotonically. This means that a higher value of any index is always better or worse than a lower value of the same index, depending on whether the efficiency function increases or decreases [12].

The TOPSIS method assumes that each criterion has a tendency of monotonically increasing or decreasing utility. Therefore, it is easy to define the ideal and negative-ideal solutions. The Euclidean distance approach was proposed to evaluate the relative closeness of the alternatives to the ideal solution. Thus, the preference order of the alternatives can be derived from a series of comparisons of these relative distances.[9]

The TOPSIS method evaluates the following decision matrix which refers to ***m*** alternatives which are evaluated in terms of ***n*** criteria:

$$\boldsymbol{D} = \begin{bmatrix} x_{11} & x_{12} & x_{13} & \cdots & x_{1n} \\ x_{21} & x_{22} & x_{23} & \cdots & x_{2n} \\ . & & & & . \\ . & & & & . \\ . & & & & . \\ x_{m1} & x_{m2} & x_{m3} & \cdots & x_{mn} \end{bmatrix}$$

Where,x_{ij} denotes the performance measure of the ***i-th*** alternative in terms of the J-th criterion. [9]

This method considers three types of attributes or criteria.

1. Qualitative benefit attributes/criteria
2. Quantitative benefit attributes
3. Cost attributes or criteria

In this method two artificial alternatives are hypothesized:

1. Ideal alternative: the one which has the best level for all attributes considered.
2. Negative ideal alternative: the one which has the worst attribute values.

TOPSIS selects the alternative that is the closest to the ideal solution and farthest from negative ideal alternative[13].

Input To Technique For Order Preference By Similarity To Ideal Solution (Topsis)

In TOPSIS assumes, ***m*** alternatives (options) and ***n***attributes/criteria and the score of each option with respect to each criterion are already present.

Let,xij score of option i with respect to criterion j

Then, a matrix X = (xij),m **x nmatrix**.

Let,***J*** be the set of benefit attributes or criteria **(more is better)**

Let,J'be the set of negative attributes or criteria **(less is better)[13]**

Steps Of Technique For Order Preference By Similarity To Ideal Solution (Topsis)

Step 1: Construct the Normalized Decision Matrix

The TOPSIS method first converts the various criteria dimensions into non-dimensional criteria as follows:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{k=1}^{m} x_{kj}^2}}$$

Step 2: Construct the Weighted Normalized Decision Matrix

A set of weights $W = (w_1, w_2, w_3 \ldots w_n)$, (where: $\Sigma w_i = 1$) defined by the decision maker is next used with the decision matrix to generate the **weighted normalized matrix** **V** as follows:

$$V = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & w_3 r_{13} & \cdots & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & w_3 r_{23} & \cdots & w_n r_{2n} \\ \cdot & & & & \cdot \\ \cdot & & & & \cdot \\ \cdot & & & & \cdot \\ w_1 r_{m1} & w_2 r_{m2} & w_3 r_{m3} & \cdots & w_n r_{mn} \end{bmatrix}$$

Step 3: Determine the Ideal and the Negative-Ideal Solutions

The **ideal**, denoted as A^*, and the **negative-ideal**, denoted as A^-, alternatives (solutions) are defined as follows:

$$A^* = \{ (\max_i v_{ij} \mid j \in J), (\min_i v_{ij} \mid j \in J'), i = 1,2,3,\ldots,m\} = \{ v_{1*}, v_{2*}, \ldots, v_{n*} \}.$$

$$A^- = \{ (\min_i v_{ij} \mid j \in J), (\max_i v_{ij} \mid j \in J'), i = 1,2,3,\ldots,m\} = \{ v_{1-}, v_{2-}, \ldots, v_{n-} \}.$$

Where: $J = \{j = 1, 2, 3\ldots n$ and j is associated with benefit criteria$\}$,

$J' = \{j = 1, 2, 3\ldots n$ and j is associated with cost/loss criteria$\}$.

The previous two alternatives are fictitious. However, it is reasonable to assume here that for the benefit criteria, the decision maker wants to have a maximum value among the alternatives. For the cost criteria, the decision maker wants to have a minimum value among the alternatives. In this step, alternative A^* indicates the most preferable alternative or the ideal solution. Similarly, alternative A^- indicates the least preferable alternative or the negative-ideal solution.

Step 4: Calculate the Separation Measure

The ***n***-dimensional Euclidean distance method is next applied to measure the separation distances of each alternative from the ideal solution and negative-ideal solution.

Thus, distances from the ideal solution is defined as follows:

$$S_{i*} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_{j*})^2}, \quad for \quad i = 1, 2, 3, \ldots, m,$$

Where, Si^* is the distance (in the Euclidean sense) of each alternative from the ideal solution.

Similarly, distances from the negative-ideal solution is defined as follows:

$$S_{i-} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_{j-})^2}, \quad for \quad i = 1, 2, 3, \ldots, m,$$

Where, Si^- is the distance (in the Euclidean sense) of each alternative from the negative-ideal solution.

Step 5: Calculate the Relative Closeness to the Ideal Solution

The relative closeness of an alternative A_i with respect to the ideal solution A^* is defined as follows:

$$C_{i*} = \frac{S_{i-}}{S_{i*} + S_{i-}},$$

$$\text{where} \quad 1 \geq C_{i*} \geq 0, \quad and \quad i = 1, 2, 3, \ldots, m.$$

Apparently, $C_{i*} = 1$, if $A_i = A^*$, and $C_{i-} = 0$, if $A_i = A^-$.

Step 6: Rank the Preference Order

The best (optimal) alternative can now be decided according to the preference rank order of C_*. Therefore, the best alternative is the one that has the shortest distance to the ideal solution. The previous definition can also be used to demonstrate that any alternative which has the shortest distance from the ideal solution is also guaranteed to have the longest distance from the negative-ideal solution.[9]

IV. A CASE STUDY ON BRICKS SELECTION USING TECHNIQUE FOR ORDER PREFERENCE BY SIMILARITY TO IDEAL SOLUTION (TOPSIS):

The computations were carried out using Microsoft Excel 2013. The decision matrix for the TOPSIS method was formed with the decision makers' evaluations of 4 bricks alternatives [Fly ash (FAL – G) bricks, Human hair bricks, Clay bricks, Sugarcane bassage ash bricks].

The Global Weight of the criteria is calculated first through Analytic Hierarchy Process (AHP) and then it is analyzed by Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method.

Table: 1 Weights and Performance of the Criteria

Weight	0.1	0.4	0.3	0.2
	Production	Compressive Strength	Eco-friendly	Cost
Fly ash (FAL – G) bricks	7	9	9	8
Human hair bricks	8	7	8	7
Clay bricks	9	6	8	9
Sugarcane bassage ash bricks	6	7	8	6

Calculation of Bricks Selection using Technique for Order Preference by Similarity to Ideal Solution (TOPSIS):

Step 1(a): Calculate $(\Sigma x^2_{ij})^{1/2}$ for each column

Table: 2 $(\Sigma x^2_{ij})^{1/2}$ for each column

	Production	Compressive Strength	Eco-friendly	Cost
Fly ash (FAL – G) bricks	49	81	81	64
Human hair bricks	64	49	64	49
Clay bricks	81	36	64	81
Sugarcane bassage ash bricks	36	49	64	36
Σx_{ij}^2	230	215	273	230
$(\Sigma x^2)^{1/2}$	15.17	14.66	16.52	15.17

Step 1(b): Divide each column by $(\Sigma x^2_{ij})^{1/2}$ to get r_{ij}

Table: 3 r_{ij} for each column

	Production	Compressive Strength	Eco-friendly	Cost
Fly ash (FAL – G) bricks	0.46	0.61	0.54	0.53
Human hair bricks	0.53	0.48	0.48	0.46
Clay bricks	0.59	0.41	0.48	0.59
Sugarcane bassage ash bricks	0.40	0.48	0.48	0.40

Step 2: Multiply each column by w_j to get v_{ij}

Table: 4 v_{ij} for each column

	Production	Compressive Strength	Eco-friendly	Cost
Fly ash (FAL – G) bricks	0.046	0.244	0.162	0.106
Human hair bricks	0.053	0.192	0.144	0.092
Clay bricks	0.059	0.164	0.144	0.118
Sugarcane bassage ash bricks	0.040	0.192	0.144	0.080

Step 3 (a): Determine ideal solution A^*.
A^* = {0.059, 0.244, 0.162, 0.080}

Table: 5 Ideal Solution A^*

	Production	Compressive Strength	Eco-friendly	Cost
Fly ash (FAL – G) bricks	0.046	0.244	0.162	0.106
Human hair bricks	0.053	0.192	0.144	0.092
Clay bricks	0.059	0.164	0.144	0.118
Sugarcane bassage ash bricks	0.040	0.192	0.144	0.080
		↑		↓

Step 3 (b): Find negative ideal solution A'.
A' = {0.040, 0.164, 0.144, 0.118}

Table: 6 Negative Ideal Solution A'

	Production	Compressive Strength	Eco-friendly	Cost
Fly ash (FAL – G) bricks	0.046	0.244	0.162	0.106
Human hair bricks	0.053	0.192	0.144	0.092
Clay bricks	0.059	0.164	0.144	0.118
Sugarcane bassage ash bricks	0.040	0.192	0.144	0.080
		↑		↓

Step 4 (a):

(i) Determine separation from ideal solution A^* = {0.059, 0.244, 0.162, 0.080}$S_i^* = [\Sigma\ (v_j^* – v_{ij})^2]^{1/2}$for each row

Table:7Separation from Ideal Solution A^*

	Production	Compressive Strength	Eco-friendly	Cost
Fly ash (FAL – G) bricks	$(0.046-0.059)^2$	$(0.244-0.244)^2$	$(0.162-0.162)^2$	$(0.106-0.080)^2$
Human hair bricks	$(0.053-0.059)^2$	$(0.192-0.244)^2$	$(0.144-0.162)^2$	$(0.092-0.080)^2$
Clay bricks	$(0.059-0.059)^2$	$(0.164-0.244)^2$	$(0.144-0.162)^2$	$(0.118-0.080)^2$
Sugarcane bassage ash bricks	$(0.040-0.059)^2$	$(0.192-0.244)^2$	$(0.144-0.162)^2$	$(0.080-0.080)^2$

(ii) Determine separation from ideal solution S_i^*

Table: 8 Separation from Ideal Solution S_i^*

	$\Sigma(v_j^* – v_{ij})^2$	$S_i^* = [\Sigma (v_j^* – v_{ij})^2]^{1/2}$
Fly ash (FAL – G) bricks	0.000845	0.029
Human hair bricks	0.003208	0.057
Clay bricks	0.008186	0.090
Sugar cane bassage ash bricks	0.003389	0.058

Step 4 (b):

(i) Find separation from negative ideal solution A' = {0.040, 0.164, 0.144, 0.118}
$S_i' = [\Sigma\ (v_j' – v_{ij})^2]^{1/2}$ for each row

Table:9separation from negative ideal solution A'

	Production	Compressive Strength	Eco-friendly	Cost
Fly ash (FAL – G) bricks	$(0.046-0.040)^2$	$(0.244-0.164)^2$	$(0.162-0.144)^2$	$(0.106-0.118)^2$
Human hair bricks	$(0.053-0.040)^2$	$(0.192-0.164)^2$	$(0.144-0.144)^2$	$(0.092-0.118)^2$
Clay bricks	$(0.059-0.040)^2$	$(0.164-0.164)^2$	$(0.144-0.144)^2$	$(0.118-0.118)^2$
Sugarcane bassage ash bricks	$(0.040-0.040)^2$	$(0.192-0.164)^2$	$(0.144-0.144)^2$	$(0.080-0.118)^2$

(ii) Determine separation from negative ideal solution S_i'

Table: 10 separation from negative ideal solution S_i'

	$\Sigma(v_j' – v_{ij})^2$	$S_i^* = [\Sigma (v_j' – v_{ij})^2]^{1/2}$
Fly ash (FAL – G) bricks	0.006904	0.083
Human hair bricks	0.001629	0.040
Clay bricks	0.000361	0.019
Sugar cane bassage ash bricks	0.002228	0.047

Step 5: Calculate the relative closeness to the ideal solution $Ci^* = S'_i / (Si^* + S'_i)$ and Rank the Preference Order

Table: 11Relative Closeness to the Ideal Solution (Ci*) and Rank the Preference Order

	$S'_i/(S_i^*+S'_i)$	C_i^*	Rank	
Fly ash (FAL – G) bricks	0.083/0.112	0.74	1	⟵ BEST
Human hair bricks	0.040/0.097	0.41	3	
Clay bricks	0.019/0.109	0.17	4	⟵ WORST
Sugarcane bassage ash bricks	0.047/0.105	0.45	2	

Thereafter, the relative closeness coefficients are determined, and four type of bricks are ranked. Obtained results have been mentioned in Table-11. Thus, Fly ash (FAL – G) bricks has the best score amongst four type of bricks.

V. CONCLUSIONS

From this research work, following conclusions are drawn:

- By above case, studyit is clear that the bricks selection involves multiple criteria which show the important role in selection of bricks. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is a simple and understandable method for selecting a suitable bricks. Using this method, different alternatives are selected according to the importance of different criteria. Thus, TOPSIS method used for different multi-criteria decision problems in a suitable manner.
- For various bricks selection, determined attribute set, determined weight of each criteria, selected criteria ranking method – TOPSIS method and presented a case study on brick selection. The proposed ranking technique shows relative distance of each bricks from the minimal requirements to the bricks. The problem's solution results show that the proposed model can be successfully applied for various bricks ranking. The problem solution result shows thatFly ash (FAL – G) bricks > Sugarcane bassage ash bricks > Human hair bricks > Clay bricks, it means, that Fly ash (FAL – G) bricks is the best and Clay bricks is the worst.
- By using Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) technique rating system can be applied on selected criteria.
- With the help of Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) technique further research work can be carried out on Ready Mixed Concrete selection as per case study.
- The proposed methodology can also be applied to any other selection problem involving multiple and conflicting criteria.

ACKNOWLEDGEMENT

The Authors thankfully acknowledge to Dr. C. L. Patel, Chairman, Charutar Vidya Mandal, and Er. V. M. Patel, Hon. Jt. Secretary, Charutar Vidya Mandal, Dr. F. S. Umrigar, Principal, B.V.M. Engineering College, Prof. J. J. Bhavsar, Associate professor and coordinator PG (Construction Engineering & Management), Civil Engineering Department, B.V.M Engineering College, Vallabh Vidyanagar, Gujarat, India for their motivations and infrastructural support to carry out this research.

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