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Identification of Major Barriers for Sustainable Development in Indian Construction Industry

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ABSTRACT: "Sustainable building" is the design and construction of buildings using methodsand materials that are resource efficient and that will not compromise the healthof the environment or the associated health and well-being of the building'soccupants, construction workers, the general public, or future generations.Sustainable building involves the consideration of many issues, including landuse, site impacts, indoor environment, energy and water use, lifecycle impacts ofbuilding materials, and solid waste. But in Indian construction industry, the sustainable development is hindered by some barriers like higher initial costs, lack of awareness in public, lack of training in sustainable construction. It is important to identify the major barriers for sustainable construction. By identifying these barriers, all the stakeholders of construction can overcome these obstructions and move towards sustainable development. In this present study, the list of barriers for sustainable development are identified from library resources and all major barriers were obtained from survey consisting the set of 23 respondents and analysed the obtained data using RRI analysis ,with a case study.

I. INTRODUCTION

"Sustainability is said to be based on five pillars: conservation ofnature, health and safety, reduced use of materials, social ecology,and cultural ecology" (Cywinski 2001).According to Bourdeau(2000), enhancement of sustainabilitycan be realized by focusing on three aspects:

1 Minimizing environmental impact;
2 Maximizing economical benefits;
3 Minimizing sociocultural impact; and

Sustainable construction, in general, refers to the applicationof the principles of sustainable development to the constructionindustry. Sustainable construction encompasses severaldimensions which, at least, involve the following

(a) Social dimension: focusing on issues such as health and safety, involvement of stakeholders, equality and diversity in the workplace and creating employment opportunities
(b) Economic dimension: focusing on issues such as whole life costing, support of local economies and financial affordability for intended beneficiaries
(c) Environmental dimension: focusing on issues such as reducing energy and water consumption, using renewable resources and minimising pollution.

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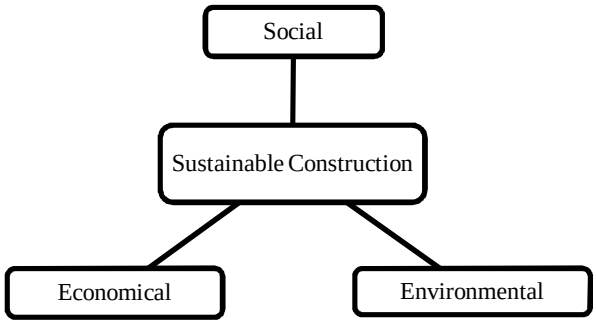

Fig 1: Three Dimensions of Sustainable Construction

There is necessity to convert conventional construction to sustainable construction for meeting the needs of the present generation withoutcompromising the ability of future generations to meet theirown. For converting from a Conventional Construction to Sustainable Construction, the project Stakeholder should know what type of barriers will occur during Planning, Construction, Post-Construction, and Operation stages of Project.

II. LITERATUREREVIEW

WorldCommission on Environment and Development (WCED,1987) defined Sustainability as "Development toensure that it meets the needs of the present withoutcompromisingthe ability of future generations to meet their own needs. Theconcept of sustainable development does imply limits–not absolutelimits but limitations imposed by the present state of technologyand social organization on environmental resources and by theability of the biosphere to absorb the effects of human activity".

According to Miyatake (1996), "Achieving sustainability through conservation,recycling, and research and development of new materialsand technologies is the next great challenge for the civil engineeringand construction industry."

There are six principles for sustainable construction, proposed by Miyakate (1996); CIB (1996)

1. Minimization of resource consumption;
2. Maximization of resource reuse;
3. Use renewable and recyclable resources;
4. Protect the natural environment;
5. Create a healthy and non-toxic environment; and
6. Pursue quality in creating the built environment.

Cywinski (2001), stated "Sustainability is said to be based on five pillars: conservation of nature, health and safety, reduced use of materials, social ecology, and cultural ecology" The last two issues are related to education and knowledge, ethics and culture, and values of heritage. Other areas of sustainability include "management and business practices, design technology and procedures, construction methods and equipment, materials and systems, and public and government policy. A list of sustainability linked environmental factors includes: energy, building ecology, air-water landscaping, waste management, cultural change, and behavioural issues".

Building Design & Construction (2003), stated the Sustainable Building as the practice of Increasing the efficiency with which buildings and their sites use energy, water, and materials, and Reducing impacts on human health and the environment through better siting, design, construction, operation, maintenance, and removal—the complete building life cycle.

Cassidy (2003), stated the sustainable building is the practice of increasing the efficiency with whichbuildings and their sites use energy, water, and materials andreducing impacts on human health and the environmentthrough better siting, design, construction, operation,maintenance, and removalthe complete building life cycle.

The review of literature revealed the existence of various barriers exist in construction industry for sustainable development. In present study, major barriers of sustainable construction are found out by using questionnaire analysis.

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The review of literature of construction contractor selection process revealed the existence of various criteria for selecting contractor, methods for evaluation of technical bid and pre-qualification of contractors.

III. METHODOLOGY

This study will be done using Relative Important Index (RII), Analytical Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Fuzzy modified Technique for Order Preference by Similarity to Ideal Solution (FMTOPSIS) and Multi Attribute Utility Theory (MAUT).

3.1 Relative Important Index (RII)

Relative Important Index Analysis (RII) is a technique used for ranking of barriers from the feedback given by various respondents. The RII can be calculated using the following equation

$$RII = \frac{\sum_{i=1}^{n} \left(w_i \times x_i \right)}{AN}$$

Where, w is the weight assigned by respondent to the barrier (ranging from 0 to 3);
x is frequency of each weightage;
A is the highest weight (3 in this study);
N is the Number of respondents in the survey.

3.2 Multi Criteria Decision Making (MCDM) Methods

Multi-criteria decision making (MCDM) is regarded as a main part of modern decision science and operational research,which contains multiple decision criteria and multiple decision alternatives. The objective of the MCDM is to find the mostdesirable alternative(s) from a set of available alternatives versus the selected criteria. The MCDM methods are able toobtain solutions for a wide range of society, economics, engineering and management problems. This study will be done using Analytical HierarchyProcess (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Fuzzy Modified Technique for Order Preference by Similarity to Ideal Solution (FMTOPSIS) andMulti Attribute Utility Theory (MAUT).

3.3Analytical Hierarchy Process (AHP)

AHP is usually used to solve a complex multi-criteria decision problem(Kumar and Ganesh, 1996). AHP is a basic approach to decision making and has been acknowledged as animportant multi-criteria decision model (Sajjad, 1999).Some key and basic steps involved in this methodologyare(Varney 1985):

Table 3.1: Nine-point intensity of importance scale and its description

Relative intensity	Definition	Explanation
1	Equal value	Two requirements are of equal value
3	Slightly more value	Experience slightly favours onerequirement over another
5	Essential or strong value	Experience strongly favours one requirement over another
7	Very strong value	A requirement is strongly favoured and its dominance is demonstrated in practice
9	Extreme value	The evidence favouring one over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate valuesbetween two adjacent judgements	When compromise is needed
Reciprocals	Reciprocals for inverse comparison	

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1. Define problem and Determine overall objective. Broaden the objectives of the problem or consider all actors, objectives and its outcome.
2. Determine attributes and establish pairwise comparison matrix.

Identify the criteria that influence the behaviour of the alternative on the objective. This requires $\frac{n(n+1)}{2}$ comparisons by using nine-point scale shown in Table 3.1, where n is the number of elements with the considerations that diagonal elements are 1 and the other elements will simply be the reciprocals of the earlier comparisons.

3. Determine alternatives.
4. Establish hierarchy.

Structure the problem in a hierarchy of different levels constituting goal, criteria, sub-criteria and alternatives.

5. Perform pairwise comparisons for alternative matrix.

Compare each element in the corresponding level and calibrate them on the numerical scale. This requires $\frac{n(n+1)}{2}$ comparisons by using nine-point scale shown in Table 3.1, where n is the number of elements with the considerations that diagonal elements are 1 and the other elements will simply be the reciprocals of the earlier comparisons.

6. Calculate eigenvalues and eigenvectors of each comparison

Perform calculations to find Eigen vector and the Maximum Eigen value.

7. Verify consistency index and ratio.

Consistency Index (CI), Consistency Ratio (CR) can be find out by using following formulae

Consistency Index, $\mathrm{CI} = \frac{(q-n)}{(n-1)}$

Consistency Ratio, $\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}}$

where q is the Maximum Eigen value

n is size of matrix

RI is the Random consistency Index (RI) is obtained from the below Table

Table 3.2: Random consistency Index

Size of the Matrix	1	2	3	4	5	6	7	8	9	10
Random Consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

8. Perform matrix calculations.

Total Score of i^{th} alternative A_i can be find out by using following formulae

Overall priority of alternative $A_i = \sum_{j=1}^{n} c_j x_{ij}$ where c_j is the preference of the criterion $C_j x_{ij}$ is the preference of an alternative A_i in the index of criterion C_j.

9. Recommend alternatives.

Rank the alternatives based on Overall priority. The alternative having highest Overall priority is considered as an ideal alternative.

3.4Technique for OrderPreference by Similarity to an Ideal Solution (TOPSIS)

Technique for orderpreference by similarity to an ideal solution (TOPSIS) is one of the well-known classical MCDM methods proposed by Hwangand Yoon for solving the decision making problems. It is based on the concepts that the

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chosen alternative should havethe shortest distance from the positive ideal point and the farthest distance from the negative ideal point concurrently. Infact, the ideal point is the solution, in which the benefit criteria are maximized and the cost criteria are minimized.

Suppose an MCDM problem that has m alternatives $A_1, A_2, ..., A_m$ and with n decision criteria, $C_1, C_2, ..., C_n$. Each alternative isassessed with respect to the n criteria.

Then, the TOPSIS method can be summarized as follows:

Step I: List out the Decision Criteria and calculate Normalized priority by using following formulae

$$P_i = \frac{p_i}{\Sigma p_i}$$

where p_i is priority of criteria i given by decision maker(s).

Step II: Form the decision matrix between alternatives and criteria based on the Decision maker responses.
All the performance ratings assigned to the alternatives with respect to each criterionform a decision matrix denoted by $X = (x_{ij})_{m \times n}$.

Step III: Normalize the decision matrix $X = (x_{ij})_{m \times n}$ using the equation below

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, i = 1,2,....,m; j = 1,2,...n$$

where r_{ij} is the normalized criteria rating.

Step IV: Calculate the weighted normalized decision matrix $V = (v_{ij})_{m \times n}$.

$v_{ij} = w_{ij}.r_{ij}$, $i = 1,2...., m,$ $j = 1,2,...., n,$ where w_{ij} is the relative weight of the j^{th} criterion, and $\sum_{j=1}^{n} w_j = 1$.

Step V: Determine the ideal and negative-ideal solutions.

$$A^* = v_1^*, v_2^*, ..., v_m^* = \left\{ \left(\max_j v_{ij} \mid j \in \Omega_b \right), \left(\min_j v_{ij} \mid j \in \Omega_c \right) \right\}, \quad A^- = v_1^-, v_2^-, ..., v_m^* = \left\{ \left(\min_j v_{ij} \mid j \in \Omega_b \right), \left(\max_j v_{ij} \mid j \in \Omega_c \right) \right\}$$

where Ω_b and Ω_c are the sets of benefit criteria and cost criteria, respectively.

Step VI: Calculate the Euclidean distances of each alternative from the positive ideal solution and the negative ideal solution,respectively.

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

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

Step VII: Calculate the relative closeness of each alternative to the ideal solution. The relative closeness of the alternative A_i with respect to A^* is defined as

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$RC_i = \frac{D_i^-}{D_i^* + D_i^-};\ 0 < RC_i \le 1;\ \ i = 1, 2, ..., m$ where RC_i the index value lies between 0 and 1. The larger index value means the better performance of the alternative. RC_i may also be called as overall or composite performance score of alternative A_i.

Step VIII: Rank the alternatives according to the relative closeness to the ideal solution. The bigger the RC_i the more desirable the alternative A_i will be. The best alternative is the one with the greatest relative closeness to the ideal solution.

3.5 Fuzzy Modified Technique for OrderPreference by Similarity to an Ideal Solution (FMTOPSIS)

The following are the steps of the FMTOPSIS method

Step I: Establish a group of k Decision Makers.

Step II: Define a set of relevant criteria and obtain rating of each criteria from each decision maker according to scale defined in Table 3.3. Separate these list of criteria into Subjective Criteria and Objective Criteria.

Subjective criterion is the criterion which can't directly measure in numerical values (e.g.: Type of past projects undertaken by contractor in contractor selection decision).Objective criterion is the criterion which can directly measure in numerical values (e.g.: Age of the organization, Turnover).

Table 3.3: Criteria rating scale for Fuzzy modified TOPSIS.

Linguistic variables	Triangular fuzzy numbers
Very high (VH)	(0.7, 0.9, 1)
High (H)	(0.6, 0.7, 0.8)
Medium high (MH)	(0.4, 0.5, 0.6)
Medium (M)	(0.1, 0.3, 0.5)
Medium low (ML)	(0, 0.2, 0.3)
Low (L)	(0, 0.1, 0.2)
Very low (VL)	(0, 0, 0.2)

Step III: Rate each alternative in index of objective criterion and obtain the rating of a potential alternative for all subjectivecriterion form each Decision maker according to the scale shown in Table 3.4.

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Table 3.4: Scale for rating alternatives for Fuzzy modified TOPSIS.

Linguistic variables	Triangular fuzzy numbers
Very Good (VG)	(9, 10, 10)
Good (G)	(7, 9, 10)
Medium Good (MG)	(5, 7, 9)
Fair (F)	(3, 5, 7)
Medium Poor (MP)	(1, 3, 5)
Poor (P)	(0, 1, 3)
Very Poor (VP)	(0, 0, 1)

Step IV: Aggregate the ratings of alternatives versus each subjective criterion $\left(\tilde{x}_{ij}\right)$ and fuzzy weights of selected criteria $\left(\tilde{w}_{ij}\right)$.

The fuzzy ratings of all DMs be triangular fuzzy numbers $\tilde{x}_{ijk}=\left(a_{ijk},b_{ijk},c_{ijk}\right),\ k=1,2,....,K$. Then the aggregated fuzzyrating can be obtained as

$$\tilde{x}_{ij}=\left(a_{ij},b_{ij},c_{ij}\right),\ k=1,2,....,K,$$

where $a_{ij}=\frac{1}{K}\sum_{k=1}^{k}a_{ijk}$,

$$b_{ij}=\frac{1}{K}\sum_{k=1}^{k}b_{ijk},$$

$$c_{ij}=\frac{1}{K}\sum_{k=1}^{k}c_{ijk}$$

Let the fuzzy weights of selected criteria be triangular fuzzy numbers $\tilde{w}_{jk}=\left(w_{jk1},w_{jk2},w_{jk3}\right),\ k=1,2,....,K$, then the aggregatedfuzzy weight of each criterion can be obtained as

$$\tilde{w}_{j1}=\left(w_{j1},w_{j2},w_{j3}\right),\ k=1,2,....,K$$

Where $w_{j1}=\frac{1}{K}\sum_{k=1}^{k}w_{jk1}$,

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$$w_{j2} = \frac{1}{K}\sum_{k=1}^{k} w_{jk2},$$

$$w_{j3} = \frac{1}{K}\sum_{k=1}^{k} w_{jk3}$$

Also, the ratings of alternatives versus each objective criterion are aggregated by the arithmetic mean.

Step V: Compute the normalized decision matrix. Vector normalization is applied to calculate r_{ij} and $\tilde{r}_{ij}$.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}},\ i = 1,2,....,m;\ \ j = 1,2,....,k-1,$$

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{e_j^*}, \frac{b_{ij}}{e_j^*}, \frac{c_{ij}}{e_j^*}\right),\ i = 1,2,....,m,\ \ j = k,....,n,$$

where $e_j^* = \sqrt{\sum_{i=1}^{m} c_{ij}}$.

Step VI: Construct the fuzzy weighted normalized decision matrix, $\tilde{V} = \left[\tilde{v}_{ij}\right]_{m\times n}$, the fuzzy weighted normalized decisionmatrix is calculated by multiplying each column of the matrix by the fuzzy weight $\left(\tilde{w}_j\right)$, which is assigned by pairwisecomparisons of elements.

Thus, $\tilde{v}_{ij} = \tilde{w}_j r_{ij},\ i = 1,2,....,m;\ \ j = 1,2,.....,k-1,$

$$\tilde{v}_{ij} = w_j \tilde{r}_{ij},\ \ i = 1,2,...,m;\ \ j = k,....,n,$$

Step VII: Defuzzify fuzzy numbers. Each fuzzy number is defuzzified by using the centroid method. For triangular fuzzynumbers $\tilde{v} = (a,b,c)$ the defuzzification centroid value is obtained by

$$\bar{v} = \frac{1}{3}(a+b+c).$$

Each centroid value for fuzzy numbers, $\tilde{v}_{ij} = \left(a_{ij}, b_{ij}, c_{ij}\right)$, contained in the weighted normalized decision matrix is

$$\bar{v}_{ij} = \frac{1}{3}\left(a_{ij} + b_{ij} + c_{ij}\right),\ i = 1,2,....,m;\ \ j = k,....n.$$

Step VIII Determine the positive ideal and negative ideal solutions. The values for A^* and A^- are defined as

$A^- = \left(v_1^-, v_2^-, ..., v_{k-1}^-, \tilde{v}_k^-, ...\tilde{v}_n^-\right)$ where

$$= \left\{\left(\min_i \tilde{v}_{ij} \middle| j \in J\right), \left(\max_i \tilde{v}_{ij} \middle| j \in \dot{J}\right), \left(\min_i \tilde{v}_{ij} \middle| j \in J\right), \left(\max_i \tilde{v}_{ij} \middle| j \in \dot{J}\right) \middle| i = 1,2,....,m\right\}$$

$J = \left\{j = 1,2,....., n \middle| j \text{ associated with benfit attribute}\right\}$ $\dot{J} = \left\{j = 1,2,....., n \middle| j \text{ associated with cost attribute}\right\}$ For benefit criterion, the DM desires to have a maximum value among the alternatives. For cost criterion, however, the DMdesires to have a minimum value among them. A^* indicates the most preferable alternative or the ideal solution.Similarly, A^- indicates the least preferable alternative or the anti-ideal solution.

Step IX: Construct ideal separation matrix $\left(D^*\right)$ and anti-ideal separation matrix $\left(D^-\right)$ which are defined as follow.

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$$D^{*}=\left[d_{ij}^{*}\right]=\begin{bmatrix} \left|\bar{v}_{11}-\bar{v}_{1}^{*}\right| & \cdots & \left|\bar{v}_{1(k-1)}-\bar{v}_{k-1}^{*}\right| & \left|\bar{v}_{1k}-\bar{v}_{k}^{*}\right| & \left|\bar{v}_{1n}-\bar{v}_{n}^{*}\right| \\ \left|\bar{v}_{21}-\bar{v}_{1}^{*}\right| & \cdots & \left|\bar{v}_{2(k-1)}-\bar{v}_{k-1}^{*}\right| & \left|\bar{v}_{2k}-\bar{v}_{k}^{*}\right| & \left|\bar{v}_{2n}-\bar{v}_{n}^{*}\right| \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \left|\bar{v}_{m1}-\bar{v}_{1}^{*}\right| & \cdots & \left|\bar{v}_{m(k-1)}-\bar{v}_{k-1}^{*}\right| & \left|\bar{v}_{mk}-\bar{v}_{k}^{*}\right| & \left|\bar{v}_{mn}-\bar{v}_{n}^{*}\right| \end{bmatrix}$$

$$D^{-}=\left[d_{ij}^{-}\right]=\begin{bmatrix} \left|\bar{v}_{11}-\bar{v}_{1}^{-}\right| & \cdots & \left|\bar{v}_{1(k-1)}-\bar{v}_{k-1}^{-}\right| & \left|\bar{v}_{1k}-\bar{v}_{k}^{-}\right| & \left|\bar{v}_{1n}-\bar{v}_{n}^{-}\right| \\ \left|\bar{v}_{21}-\bar{v}_{1}^{-}\right| & \cdots & \left|\bar{v}_{2(k-1)}-\bar{v}_{k-1}^{-}\right| & \left|\bar{v}_{2k}-\bar{v}_{k}^{-}\right| & \left|\bar{v}_{2n}-\bar{v}_{n}^{-}\right| \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \left|\bar{v}_{m1}-\bar{v}_{1}^{-}\right| & \cdots & \left|\bar{v}_{m(k-1)}-\bar{v}_{k-1}^{-}\right| & \left|\bar{v}_{mk}-\bar{v}_{k}^{-}\right| & \left|\bar{v}_{mn}-\bar{v}_{n}^{-}\right| \end{bmatrix}$$

Step X: The CI is calculated by

$$CI=\xi_{i}+\Im_{i}$$

$\xi_{i}\left(D^{*},D^{-}\right)=\left(\sum_{i=1_{(A)}}^{K}\frac{d_{ij}^{*}}{d_{ij}^{-}}\right)^{\frac{1}{2}}+Z_{if}\ \ \forall i=1,2,\ldots..,m,$ where the first summation $\left(\Sigma_{A}\right)$ refers to all j for which $d_{ij}^{-}>0$ while $\left(Z_{ij'}\right)$ refers to all j' for which $d_{ij}^{-}=0.$ Moreover $Z_{ij'}$ canbe calculated such that

$$Z_{ij'}=\left(\max_{j'}\left(\frac{d_{ij'}^{*}}{d_{ij'}^{-}}\right)\right)^{\frac{1}{\max_{j}w_{j}}}\ \text{for which}\ d_{ij'}^{-}>0\ \textit{and}\ w_{j}\ \textit{for}\ d_{ij'}^{-}=0.$$

$$\Im\left(D^{*},D^{-}\right)=\left(\sum_{l=1}^{K}d_{ij}^{*}\right)^{\frac{1}{m}}+\left(\sum_{l=1_{(A)}}^{K}\frac{1}{d_{ij}^{-}}\right)^{\frac{1}{k}}+Q_{ij'}\ \ \forall i=1,2,\ldots.,m,$$

where the second summation $\left(\Sigma_{A}\right)$ refers to all j for which $d_{ij}^{-}>0$ while $\left(Q_{ij'}\right)$ refers to all j' for which $d_{ij}^{-}=0$

$Q_{ij'}=\left(\min_{j'}\left(d_{ij}^{-}\right)\right)^{\max_{j}w_{j}}$ for which $d_{ij'}^{-}>0\ \textit{and}\ w_{j}\ \textit{for}\ d_{ij'}^{-}=0.$

Step XI: Rank the preference order. The best satisfactory alternative can be determined according to preference rank orderof ξ_{i} and $\Im_{i}$. Minimum values of the CI indicate the better performance for the alternative i.

3.6 Multi-Attribute Utility Theory (MAUT)

Multi –Attribute Utility Theory (MAUT) is Multi Criteria Decision method based on utilitytheory. The method takes into consideration decision-makers' preferences in the form ofutility functions which are defined over a set of attributes (i.e. criteria).

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

Additive Model:

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

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

1) Setting the Objective and Establishing the Attributes for the Goal

A concrete target establishment and attribute identification are crucial stages for an evaluating process by using the MAUI. To begin with, a goal of the evaluation is explicitly defined, and directly related attributes are determined.

2) Creating Quantitative Figures of the Attributes

In this step the decision maker have to form decision matrix for alternatives based on each attribute. If there are m alternatives and n attributes, then the decision matrix will be

$$X = \left[x_{ij} \right]_{m \times n}$$

3) Deriving the Utility Functions of Each Attribute

This stage is where a function form of a single-attribute utility function, which is an element of the multi-attribute utility function, is determined. Utility function can be obtained from the following equation

$$u_j\left(x_{ij}\right) = \frac{x_{ij} - x_j^-}{x_j^+ - x_j^-}$$

where x_j^+, x_j^- are the highest and least decision values of j^{th} attribute.

4) Calculating the Weighting Factors of Each Attribute

This stage is where the decision makers determine the relative importance of variousattributes. The general method is a swing technique where the decision makers label a weighted value after setting the rank of the attributes in the order of their importance.

By using weightages given by decision maker, the weighting factors of each attribute can be find out by using the following formulae

$$k_j = \frac{w_j}{\sum_{j=1}^{n} w_j}$$

where w_j is the weightage of j^{th} attribute.

5) Deriving the Multi-Attribute Utility Function each Alternative

With the previously-calculated utility function of each attribute and the weighting factors, an evaluation index is developed for the general goal. In brief, to select an alternative, it can be expressed by the multi-attribute utility function, which is a single mathematical equation that shows how much these attributes contribute to the goal. The multi-attribute utilityfunction an alternative can be found out by following equation

$$U_i = k_1 u_1\left(x_{i1}\right) + k_2 u_2\left(x_{i2}\right) + \ldots + k_n u_n\left(x_{in}\right) = \sum_{j=1}^{n} k_j u_j\left(x_{ij}\right)$$

Rank the alternatives according to the Utility value. The bigger the Utility value the more desirable the alternative.

Multiplicative Model:

The following are the steps involved in MAUT for ranking alternatives.

1. Construct pay-off Matrix from Decision Maker's responses
2. Calculate range for each attribute

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3. Ranking of scaling constants (k_i) of the criteria
4. Determination of indifference points
5. Derivation of single and multi-attribute utility functions
6. Determination of values of scaling constants
7. Ascertaining the attitude of the decision maker based on overall scaling constant.
8. Ranking of the alternatives based on the utility values. Highest utility alternative is best.

Building the Utility Function:

To determine the utility value, there are six steps.

1. Identify significant design attributes and generate alternative designs
2. Find the range for each attribute and verify relevant attribute conditions
3. Use the lottery to determine the user's preference
4. Evaluate Single Attribute Utility (SAU) function and trade-off preferences
5. Combine SAUs into Multi-Attribute Utility function (MAU)
6. Select alternative with the highest MAU value by ranking the alternative.

Multiplicative Equation:

$$U(x)=\frac{1}{K}\left[\prod_{j=1}^{n}\left(1+K k_j u_j(x_j)\right)-1\right]$$ where x_j is the performance level of attribute j ,

$u_j(x_j)$ is the SAU for attribute j ,

k_j is the single attribute scaling constant, and

K is the normalizing constant which scales $0 \le U(x) \le 1$

IV. DATA COLLECTION AND ANALYSIS

Obtaining sound data is perhaps the most important and demanding aspect of theresearch process. There are several data collectionmethods, each with its' own advantages and disadvantages. These methods include interview,questionnaire survey, observation, unobtrusive methods, documents and historical data. Theuse of appropriate data collection method greatly enhances the robustness of data and,therefore, the value of the research.Survey is an efficient data collection mechanism in situations what is requiredand how to measure the variables of interest is exactly known. Sound survey design shouldfocus on three areas – general appearance of the survey, wording of questions, and planningof issues of how the variables will be categorized, scaled and coded after collection ofresponses. While designing the survey all these considerations are taken into account to helprespondents enable to understand the questions without difficulty and to provide a meaningfulresponse thereby improving the response rate and increasing the chance of getting moreconclusive inferences during data mining process.

First of all, preliminary interviews were conducted in anattempt to filter out irrelevant barriers from the preliminary set of barriers selected onthe basis of survey. Based on the information gathered through preliminary interviews, asurvey format based questionnaire was designed.

A structured survey is a pre formulated written set of questions to which respondent record their answers, usually define the type of barrier. This survey was done on total 23 respondents. The respondents of survey consists of 1 Associate Professor, 3 Assistant Professors, 4 Ph.D. Scholars, 15 M.Tech students. The Survey data is shown in Table 4.1.

Relative Rate Index (RRI) is adopted in the selection of criteria using five-point Likert scale. Respondents were asked to indicate the level of importance of these barriers on a five-point Likert's scale. **I**means barrier is **Irrelevant**, **0** means **Not a Barrier**, **1** means **Minor Barrier**,**2** means **Moderate barrier**, **3** means is **Major barrier**.

The barriers with RRI values greater than 0.7 are treated as Major barriers and sorted them according to the attributes.Criteria for selecting ideal contractor are developed based on these barriers.

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V. CASE STUDY

Validation of the various decision making models for the ideal contractor selection process is discussed in this chapter with a case study. Also, the contractors are evaluatedby respondents using a survey form given in Appendix. The various multi criteria decisionmaking methodologies like Analytical Hierarchy Process (AHP), Technique for OrderPreference by Similarity to an Ideal Solution (TOPSIS), Fuzzy Modified Technique for OrderPreference by Similarity to an Ideal Solution (FMTOPSIS) and Multi Attribute Utility Theory(MAUT) for both Addition and Multiplication are compared and the features of these modelsare discussed.
The details of case study are:

Name of the work	:	Construction of Academic Building (Basement+G+6) for Chemical Engineering Department for National Institute of Technology (NIT) at Warangal, Telangana, including Internal water supply, Sanitary installations, Drainage, Electrical Installations, Lifts, Firefighting and Fire alarm system.
Estimated Cost	:	**Rs 49,67,54,383/-**
Period of completion	:	600 days
Date of Commencement	:	15/01/2015
Date of Completion	:	05/09/2016
Last date & Time of online submission of bid	:	Up to 16:30 Hours on 25/09/2014
Time and date of online opening of Technical Bid		12:30 hours on 26/09/2014

Model	**Rank for Contractors**			
	A	**B**	**C**	**D**
AHP	III	II	**I**	IV
TOPSIS	III	II	**I**	IV
Fuzzy Modified TOPSIS	III	II	**I**	IV
MAUT Addition	III	II	**I**	IV
MAUT Multiplication	III	II	**I**	IV

Based on the five different methods for selection of ideal contractor, it can be stated that **Contractor C** is best suited for Client's requirements compared to other contractors.

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VI. CONCLUSIONS

Twelve major barriers of sustainable construction are identified based on RRI analysis. The criteria with RRI value > 0.70 are considered as major barriers.

i. Lack of training/education in Sustainable design/construction
ii. Resources and knowledge are inadequate in order to ensure proper supervising and the realization of the client's targets for Sustainable Buildings.
iii. Short pay-back time is more important than long-term positive effects
iv. Buyers do have no information about the alternatives and possibilities of Sustainable Buildings
v. Process lacks a team that manages the overall design of Sustainable Buildings
vi. Products not available in my area: lack of "green" material suppliers
vii. Lack of technical understanding on the part of others on the project team.
viii. New kind of solutions is risks with regard to costs and quality.
ix. Buyers do not want to pay extra for sustainable buildings performance
x. Manufacturers do not put adequate efforts for development of improved sustainable performance of products.
xi. Lack of methods for Refurbishment of Sustainable Buildings
xii. Buyers do not have information about the effect of Sustainable Buildings on operational costs

1. Lack of knowledge of sustainable construction techniques, information about cost and benefits of sustainable buildings, lack of sustainable construction materials in the locality, resistance to change in construction processes are some of the important parameters for a sustainable construction practice.
2. To move the sustainable construction forward, professional and educational bodies should raise the level of awareness of sustainable development across the whole society.
3. The case study presented in the work shows how the different criteria are selected and different MCDM methods adopted for analysing the technical part of the tender document.
4. Form the result obtained from AHP method, it can be concluded that **Contractor C** has the highest utility value **0.43714** with rank one. Also criteria $\mathbf{C_2}$ i.e., of Key Personnel with knowledge of sustainable construction and its methodology has the higher weightage with **0.252**.
5. Fromthe result obtained from the TOPSIS method, it can be concludedthat **Contractor C** is ranked at one with**0.70175** relative closeness to ideal solution.
6. Fromthe result obtained from the FMTOPSIS method, it can be concludedthat **Contractor C** is ranked at one with collective index of **3.860**.
7. From MAUT analysis it can be observed that **ContractorC** has the highest utility value and is ranked first. The utility value is **0.747** in **MAUT addition method**, while itis **0.85234** in **MAUT Multiplication method**.
8. **Contractor C** is an ideal contractor among the all contractors attended for the bidding part of the present work.This contracting company got strong rating in Experience in construction of Green Rating Buildings, Key Personnel with knowledge of sustainable construction and its methodology, Age and Registration of Construction Company, Availability of Manpower, Plant and Equipment.

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