Non-Profit Organization Project Selection Process Using the Hygiene Method of Multi-Criteria Decision Making

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Abstract-With the fast increase in technological development and society's needs, using Multi-Criteria Decision Making (MCDM) as a solution to tackle problems faced during a project's life cycle in different engineering fields gains interest. The use of artificial intelligence gave new opportunities to deal with problems faced during the optimization of unknown or known solutions and methods. Even more, the application of optimized solutions can be developed or modified by using different optimization approaches and methods. This paper proposes a model for the project selection process for non-profit organizations that have a limited budget and social factors strictly related to the selection process. This method is based on MCDM and takes into consideration criterion weights and experts' evaluation of projects according to the selection criteria using the hygiene method consisting of two stages, fuzzy logic, and TOPSIS.

Keywords-multi criteria decision making; TOPSIS; fuzzy logic; project selection; decision making; optimization

I. INTRODUCTION

MCDM can be considered as an applicable solution to overcome the constraints raised and need to be optimized in different engineering fields. Some optimization methods discussed in published papers are: Analytical Network Process (ANP), Visekriterijumska Optimizacija I Kompromisno Resenje (VIKOR), Artificial Neural Networks (ANNs), Analytical Hierarchy Process (AHP), Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE), and the Technique of Order Preference by Similarity to Ideal Solution (TOPSIS). This paper introduces a hygiene method for the project selection process of non-profit organizations. Most papers related to project selection depend mainly on economic measures (numerical) neglecting the social factors that affect the selection process.

II. MULTI CRITERIA DECISION MAKING APPLICATION

A. *Civil Engineering*

PROMETHEE and AHP ranking proposals were used at the project construction sector and 7 critical paths of project were examined with triangular fuzzy numbers to evaluate path selection criteria in [1]. VIKOR approach was also used to detect the critical path. In addition, fuzzy analytical network process was adopted in [2] in order to find activities' priority and correlation. A methodology named Construction Method Selection Model (CMSM) was introduced in [3], which consists of two main stages to assess and select the prefabrication construction method for projects. At first, the strategic stage, using Simple Multi-Attribute Rating Technique (SMART) resulted to 4 main attributes (project characteristics, market attribute, site conditions, and local regulations) and 12 sub – attributes with higher relative weights to project characteristics sub – attributes. The main objective of this stage was to assess the feasibility of the prefabrication process through the mentioned attributes. The second stage is the tactical stage, in which Multi-Attribute Utility Theory (MAUT) is used to evaluate the uncertainty associated with the project prefabrication ability taking sustainability performance into consideration.

A guidance method was proposed in [4] for engineering designers to select sustainable building materials depending on two main issues: evaluation criteria and stakeholder's requirements. The evaluation criteria were recognized using the sustainable Triple Bottom Line (TBL) method and the impact of each factor was determined by experts before applying the data to the Fuzzy Extended AHP (FEAHP) to get the final results. The sustainable assessment depends on 3 major categories: environmental, social-economic, and technical. More than 20 sub categories were directly responsible for the material evaluation process. The researchers used varimax rotation to reveal the correlation between the observed and latent criteria [4].

Ambiguities associated with project selection were studied using Fuzzy TOPSIS (FTOPSIS) in [5] to support contractors to choose the best project for bidding according to their abilities and the project requirements. This method is considered one of the multi attribute decision making methods

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that give an acceptable representation to real world problems. The research uses triangular fuzzy number to represent verbal factors. The best alternative selection process was examined in [6] by project evaluation and selecting the best projects using Additive Ratio Assessment (ARAS) and AHP. AHP was used to build and assess the selection process structure and assign weights to the selection criteria while ARAS performed project ranking. This method cannot deal with qualitative criteria unless they are evaluated on a numerical scale.

Authors in [7] discuss the assessment of infrastructure design methods by embracing the Monte Carlo optimization multi attribute selection model. One of the main ruling factors of the process is the epistemic uncertainty risk that differs from each method to another. Authors in [8] described MCDM methods in relevance to their usage fields and their contribution in maintenance management. AHP was adopted in [9] to design a dynamic decision model for inspecting and maintaining reinforced concrete structures. The model aims to select the best alternative by pair-wise comparison between the criteria with global priority vector instead of depending on experts' opinions.

B. Environmental Engineering

Environmental engineering has its share of using artificial intelligence. TOPSIS and ANP were used in [10] to analyze the construction methods in accordance to the productivity aspect. The main analyzing factors are management, materials, costs, time, human force, environmental sustainability, planning, and architectural design with overall 24 sub-factors. The impact of factors is examined by the Decision Making Trial and Evaluation Laboratory Method (DEMATEL). Construction and demolition waste were optimized using a proposed methodology to support decision makers in [11]. The methodology consists of 3 main stages: At first, an index system is established depending on technical, financial, environmental, and social attributes. The second stage is the evaluation framework with experts' opinions through a multi criteria decision framework using the Trapezoidal Fuzzy Numbers (TrFN), interval numbers, and Triangular Fuzzy Numbers (TFN). The next stage is examining the correlation between the criteria using the ANP to detect the main and sub criteria in order to use the fuzzy Multi-Attributive Border Approximation area Comparison (MABAC) method as a final ranking tool. Fuzzy ANP (FANP) was exploited in [12] to build a methodology for sustainable project selection depending on criteria defined by experts' opinions. A multi criteria optimization procedure was introduced in [18] to develop and evaluate 5 renewable energy scenarios. PROMETHEE method was used taking into consideration the evaluation criteria and their weights. The Simos method was used for weight determination.

C. Transportation Engineering

Authors in [13] considered the problems related to the transportation sector problem solution optimization. They introduced an assessment for technologies used in 6 public transportation fare collection methods. The authors used were AGREPREF as an MCDM method to evaluate the methods according to 6 criteria (operation costs, safety, speed, demand of applications, multipurpose, simplicity and comfort). The public transportation project selection problem in Istanbul city brought in the spotlight the use of optimization solutions [14]. A mathematical model was built in [14] by integer linear programming with IBM ILOG CPLEX 12.6.2 program. The selection process depended on selection constraints which are budget, travel time, station number accessed, and travel distance. The model's objective function looked to maximize the benefits from project proposals. The review in [15] worked with more than 50 papers from 1982 to 2019 and summarized the alternative multi criteria transport project evaluation methods instead of cost effective analysis.

D. Geotechnical Engineering

Geotechnical engineering tends to use the Particle Swarm Optimization (PSO) method due to the nonlinear behavior of the considered variables. Authors in [16] wrote a review paper on the use of PSO in various geotechnical engineering aspects. PSO was used in [17] to solve geotechnical difficulties related to slope stability, retaining wall, and shallow footings.

III. THE PROPOSED MODEL

Project selection is a very complex process. One of the most common goals is optimizing resource utilization. This process may be easier for private and marketing companies which use economic measures to evaluate the proposed project in addition to risk management taking into consideration organization resources. For government organizations, the social aspect enters as an active factor. Social goals and similar criteria are judged by experts or decision makers. For better understanding of the project selection process, some abbreviations need to be defined:

P_i: The proposed project ($P_1, P_2, \ldots, P_i$)

Cr_j: Selection criteria ($Cr_1, Cr_2, \ldots, Cr_j$)

X_{ij}: Project evaluation according to the criteria

E: no. of experts (1, 2, …, e)

The proposed model uses trapezoidal fuzzy number to evaluate the qualitative criterion shown in Figure 1. The fuzzy number is calculated according to (1). The values of verbal evaluations responding to each trapezoidal fuzzy number are stated in Table I.

$$X_{ij} = (F_{ije}, G_{ije}, L_{ije}, M_{ije})$$

$$\mu(x) = \begin{cases} 0 & X < T_1 \\ \frac{X - T_2}{T_2 - T_1} & T_1 \le X \le T_2 \\ 1 & T_2 \le X \le T_3 \\ \frac{X - T_3}{T_4 - T_3} & T_3 \le X \le T_4 \\ 0 & X < T_4 \end{cases} \qquad (1)$$

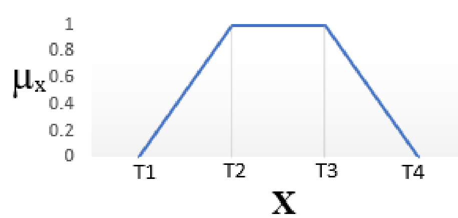

Fig. 1. Trapezoidal fuzzy numbers.

TABLE I. LINGUISTIC EVALUATION

Qualitative evaluation	Fuzzy number value
Very Low (VL)	(1, 1, 1.2, 2.8)
Low (L)	(1.2, 2.8, 3.2, 4.8)
Medium (M)	(3.2, 4.8, 5.2, 6.8)
High (H)	(5.2, 6.8, 7.2, 8.8)
Very High (VH)	(7.2, 8.8, 9, 9)

Each project evaluation provided by individual experts is multiplied by its own criteria weights. In order to aggregate experts' opinion regarding the proposed projects with respect to the selection process, criterion aggregating of fuzzy numbers needs to be performed according to the following equations:

$$\tilde{x}_{ije} = (F_{ije}, G_{ije}, L_{ije}, M_{ije})$$

$$F_{ij} = \text{Min}\ (F_{ije}) \quad (3)$$

$$G_{ij} = \frac{1}{e}\sum_{e=1}^{e} G_{ije} \quad (4)$$

$$L_{ij} = \frac{1}{e}\sum_{e=1}^{e} L_{ije} \quad (5)$$

$$M_{ij} = \text{Max}\ (M_{ije}) \quad (6)$$

The selection criteria can be categorized into benefit criteria (maximum value is preferred) or cost criteria (minimum value is preferred) according to the criteria category normalization equations. If the criterion is a benefit criterion we have:

$$\tilde{x}_{ij} = \left(\frac{F_{ij}}{\text{Max}.M_{ij}}, \frac{G_{ij}}{\text{Max}.M_{ij}}, \frac{L_{ij}}{\text{Max}.M_{ij}}, \frac{M_{ij}}{\text{Max}.M_{ij}}\right) \quad (7)$$

If it is a cost criterion:

$$\tilde{x}_{ij} = \left(\frac{\text{Min}.F_{ij}}{M_{ij}}, \frac{\text{Min}.F_{ij}}{L_{ij}}, \frac{\text{Min}.F_{ij}}{G_{ij}}, \frac{\text{Min}.F_{ij}}{F_{ij}}\right) \quad (8)$$

The next step is performing defuzzification for the input values using the middle of maxima that will used at the second stage of optimization process matrix according to (9):

$$\mu_{X_{ij}} = \frac{(M_{ij}-F_{ij})\,(L_{ij}-G_{ij})}{2} \quad (9)$$

The vector normalization deals with the input criteria according to (10).

$$\bar{x}_{ij} = \frac{x_{ij}}{\sqrt[2]{\sum_{i=1}^{i}(x_{ij})^2}} \quad (10)$$

The resulting matrix will be the Normalized Decision Matrix (NDM). NDM will be multiplied by criteria weights to determine the Weighted NDM (WNDM) as shown in (11).

$$NDM = \begin{bmatrix} \bar{x}_{11} & \bar{x}_{12} & \cdots & \bar{x}_{1j} \\ \bar{x}_{21} & \bar{x}_{22} & \cdots & \bar{x}_{2j} \\ \vdots & \vdots & \ldots & \vdots \\ \bar{x}_{i1} & \bar{x}_{i2} & \ldots & \bar{x}_{ij} \end{bmatrix}$$

$$\bar{x}_{wij} = \bar{x}_{ij} \times W_m \quad (11)$$

$$WNDM = \begin{bmatrix} w_1\bar{x}_{11} & w_2\bar{x}_{12} & \cdots & w_j\bar{x}_{1j} \\ w_1\bar{x}_{21} & w_2\bar{x}_{22} & \cdots & w_j\bar{x}_{2j} \\ \vdots & \vdots & \cdots & \vdots \\ w_1\bar{x}_{i1} & w_2\bar{x}_{i2} & \ldots & w_j\bar{x}_{ij} \end{bmatrix}$$

The next step is detecting the best and worst ideal values for each criterion according to its behavior, either it is a cost criterion, where minimum value is preferred or a benefit criterion where maximum value is preferred, in order to find the Euclidean distance from the proposed solution to the best and worst ideal solutions using (12) and (13) respectively.

$$D_i^+ = \sqrt[2]{\sum_{i=1}^{i}\left(\bar{x}_{wij} - X_{ij}^+\right)^2} \quad (12)$$

$$D_i^- = \sqrt[2]{\sum_{i=1}^{i}\left(\bar{x}_{wij} - X_{ij}^-\right)^2} \quad (13)$$

The distance between the proposed solution and the ideal best and worst solutions will be calculated by (14):

$$D_i = \sqrt[2]{(X_2 - X_1)^2 + (Y_2 - Y_1)^2 + (Z_2 - Z_1)^2} \quad (14)$$

The performance score function that will rank the proposed projects is shown in (15)

$$Pi = \frac{D_i^-}{D_i^+ + D_i^-} \quad (15)$$

IV. AN ILLUSTRATIVE EXAMPLE

In this example, we consider a group of 6 projects with an expert committee consisting of 3 experts. Projects will be evaluated regarding 5 criteria which are the quantitative criteria Cr_1 (project cost) and Cr_2 (number of beneficiaries) and the qualitative criteria Cr_3 (organization staff expert), Cr_4 (project legal constraints), and Cr_5 (project meets end-user requirements). The owner organization has the expert weights and the weights regarding the quantitative criteria as shown in Tables II and III. The expert evaluations according to the qualitative criteria are shown in Table IV.

TABLE II. EXPERT WEIGHTS

Expert	Weight
E1	High
E2	Very High
E3	High

TABLE III. QUANTITATIVE CRITERIA

	Cr_1	Cr_2
Projects	Cost	Benefit
P1	1,125,000,000	2000000
P2	4,300,000,000	265000
P3	1,050,000,000	140000
P4	4,400,000,000	1170000
P5	4,700,000,000	180000
P6	450,000,000	1200000

TABLE IV. EXPERTS EVALUATIONS ON QUALITATIVE CRITERIA

	Expert 1			Expert2			Expert3		
	Cr_3	Cr_4	Cr_5	Cr_3	Cr_4	Cr_5	Cr_3	Cr_4	Cr_5
P1	M	L	H	VH	H	M	L	M	H
P2	H	H	VL	VL	H	H	H	VL	L
P3	VL	VH	M	L	VH	L	H	H	VL
P4	VL	H	VL	VL	VH	H	VL	H	VL
P5	L	VH	H	H	L	VH	M	M	M
P6	VL	L	M	VH	M	VL	H	VH	L

The experts' evaluations for criteria weights are aggregated and normalized using trapezoidal fuzzy numbers in order to be transformed to crisp value taking into consideration the relative importance of expert weights shown in Table V. All the outputs will be used as input to TOPSIS. The calculation steps and their results are shown in Tables VI-X.

TABLE V. CRITERIA EVALUATION

Criterion	**E_1**	**E_2**	**E_3**	**Crisp %**
Cr_1	VH	VH	H	24%
Cr_2	H	VH	H	22%
Cr_3	M	H	M	17%
Cr_4	H	H	M	19%
Cr_5	H	M	H	18%

TABLE VI. QUALITATIVE CRITERIA FUZZY OUTPUT

Project	**Cr_3**	**Cr_4**	**Cr_5**
	Benefit	**Cost**	**Benefit**
P1	0.4869	0.4698	0.3852
P2	0.4819	0.4740	0.4899
P3	0.4914	0.3489	0.4866
P4	0.4344	0.3522	0.4854
P5	0.4896	0.4572	0.4260
P6	0.4905	0.4684	0.4779

TABLE VII. NORMALIZED MATRIX

	Cr_1	**Cr_2**	**Cr_3**	**Cr_4**	**Cr_5**
P1	0.1423	0.7597	0.4145	0.4440	0.3417
P2	0.5439	0.1007	0.4103	0.4480	0.4346
P3	0.1328	0.0532	0.4183	0.3297	0.4317
P4	0.5565	0.4444	0.3698	0.3328	0.4306
P5	0.5945	0.0684	0.4168	0.4321	0.3779
P6	0.0569	0.4558	0.4176	0.4427	0.4240

TABLE VIII. WEIGHTED NORMALIZED MATRIX

	Cr_1	**Cr_2**	**Cr_3**	**Cr_4**	**Cr_5**
P1	0.0341	0.1698	0.0698	0.0827	0.0623
P2	0.1303	0.0225	0.0691	0.0834	0.0792
P3	0.0318	0.0119	0.0705	0.0614	0.0787
P4	0.1334	0.0993	0.0623	0.0620	0.0785
P5	0.1425	0.0153	0.0702	0.0804	0.0689
P6	0.0136	0.1019	0.0703	0.0824	0.0773

TABLE IX. IDEAL BEST AND WORST SOLUTIONS

	Cr_1	**Cr_2**	**Cr_3**	**Cr_4**	**Cr_5**
V-	0.1425	0.0119	0.0623	0.0834	0.0623
V+	0.0136	0.1698	0.0705	0.0614	0.0792

TABLE X. PERFORMANCE AND PROJECT RANKING

	S -	**S +**	**Pi**	**Ranking**
P1	0.1917	0.0340	0.8492	**1**
P2	0.0243	0.1892	0.1140	**5**
P3	0.1143	0.1589	0.4183	**3**
P4	0.0919	0.1392	0.3978	**4**
P5	0.0112	0.2023	0.0527	**6**
P6	0.1581	0.0711	0.6897	**2**

V. CONCLUSION

MCDM methods have the advance of a methodology that tackles problems characterized by multi variable conditions, factors, and constraints. Even more, the high level of work and research continuously develops many algorithms, and optimization methods. The of fuzzy logic, genetic algorithms, and real life phenomena simulations like Ant Colony Optimization, Grey Wolf Optimization, Particle Swarm Optimization, etc. enriched the optimization approach. These methods lead to deep learning and machine learning aspects. These technologies make a solid base for the exploitation of future opportunities and new challenges that will be tackled.

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