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A TWO-FOLD HYBRID DECISION MAKING MODEL FOR SOLVING TEAM SELECTION PROBLEM UNDER UNCERTAIN CONDITIONS

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ABSTRACT

The decision making is both an art and a science. It involves the process of critical and logical thinking by the Decision maker (DM) so as to come to a finite decision on a specific scenario. The main objective of this research work is to develop a novel two way decision model that integrates the two dominant decision making methods namely Analytical Hierarchical Processing (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), for solving team selection problem (TSP). The AHP is used for choosing optimal weights and the TOPSIS is used for choosing optimal compromise solution. We combine the creditability of the two methods to propose a hybrid decision making model (DMM). We make an empirical investigation to validate the efficacy of the proposed model by collecting data for TSP. An illustrative example is depicted for better understanding the scenario.

Keywords: team selection, AHP, TOPSIS, decision making.

1. INTRODUCTION

Decision making on a bigger scene is both an art and a science that involves effective structuring of logical and rational thinking(Hansson, 1994). DMs drive solutions to complex decision making problem with the help of decision making methods. These methods choose an optimal alternative from a given set of alternatives based on several attributes that relates itself closely(Iwamoto and Fujita, 1995). The optimal alternative is chosen which is termed as the compromise solution.

The TSP is an interesting multi criteria decision making (MCDM) problem that involves several attributes that govern towards an optimal personnel selection. Based on these competing attributes the DM makes an intelligent choice. The problem describes a scenario in which, Out of N known alternatives judged based on M competing criteria, one alternative is to be chosen for doing the project. This chosen alternative is said to be a compromise solution consisting of k personnel. The skeleton schema of the decision matrix is shown in Table-1.

Table-1. Schematic representation of decision matrix.

Decision matrix	C_1	C_2	⋯	C_M
A_1	f_{11}	f_{12}	⋯	f_{1M}
A_2	f_{21}	f_{22}	⋯	f_{2M}
⋯	⋯	⋯	⋯	⋯
A_N	f_{N1}	f_{N2}	⋯	f_{NM}

The alternatives are represented by a set A = $[A_1$to $A_N]$;criteria C = $[C_1$ to $C_M]$ and the choice value or fitness value is represented by f_{11} to f_{NM}. The fitness values f_{ij} means the fitness value corresponding to the i^{th} alternative and j^{th} criteria. We proposed a novel model that uses two most dominant ranking schemes for its evaluation process. The proposed model is tested for its validity and efficacy by applying it to a real time TSP (Baležentis, Baležentis, and Brauers, 2012b). The problem has eight attributes being considered by the decision making committee and four alternatives. These eight attributes are qualitative in nature. For our case we simplify the situation by considering four attributes with two cost and two benefit factors. Out the four alternatives, one alternative is chosen as a compromise solution. Here we consider the alternatives to be a group of k personnel. So our objective is to choose an optimal group for doing a project. The details of the two methods are shown in next section.

The remainder of the research is organized as Section 2 for related works, followed by Section 3 for proposed methodology, section 4 for Results and Discussion and section 5 conclusions.

2. RELATED WORKS

The problem of MCDM is a long term issue dealt by many organizations in several regards. Many researchers have evolved and proposed new techniques to solve the MCDM problem. There are several areas that are being concentrated by the researchers. The methods are categorized as legacy and modern schemes. In the legacy scheme we observed that the decisions were made based on logical and rational reasoning. These methods included voting mechanism(Ganihar, Joshi, Patil, Mudenagudi, & Okade, 2014), dotmocracy principles, concepts of Delphi (Gordon, 2009)etc. Some state of the art decision theories are also developed for making wise decisions at critical times. Most frequent ideas include the dominance theory, possibility theory, probability theory, random process theory etc(Hansson, 1994). These logical reasoning techniques lacked effective formulation and proof statements. So to overcome these limitations formal legacy methods were introduced. A novel ranking scheme based on pair wise comparison of the alternatives was developed which was termed as Analytical Hierarchy Process (AHP) (Satty T L, 1990). (Triantaphyllou and Mann, 1995) developed a set of engineering problems and gave innovative and meaningful solutions using AHP. Also,

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(Saaty, 2008) developed priority scales for pair wise comparison and inconsistency measure to determine the inconsistency ratio for making a healthy decision. The common but a powerful variant of AHP is the Analytical Network Process (ANP) that is used for different personnel selection like the contractor and pilot selection(Cheng and Li, 2004; LEE, WU, and TZENG, 2008; Saaty, 2013; Sadeghi, Rashidzadeh, and Soukhakian, 2012; Üstün, 2011).Another extension using the grey relation with the hierarchy that is used for the call centre site selection (Birgün, 2014). Researchers also developed a few other state of the art legacy methods like WASPAS, MOORA, rank ordering etc. WASPAS is a ranking scheme that follows weighted aggregated sum product assessment that is used for making valuable decision at a manufacturing firm (Chakraborty and Zavadskas, 2014). MOORA is another such ranking scheme that is based on the multi objective optimization by ratio analysis. It is used in many engineering application from material to personnel selection(Brauers and Zavadskas, 2010; Ghorabaee, Amiri, Sadaghiani, and Zavadskas, 2015; Hafezalkotob, Hafezalkotob, and Sayadi, 2016; Zavadskas, Turskis, and Tamošaitiene, 2016). Rank ordering is a fuzzy based approach for electing an optimal alternative based on polling mechanism (Zadeh, 2004).

The MCDM methods evolved over time and researches moved from legacy methods to modern approaches. These modern techniques included the classification of ranking methods as value measurement model, goal and aspiration model and outranking models(Baležentis, Baležentis, and Brauers, 2012a). The modern approaches deals with the latter two categories. Some popular methods are the TOPSIS(Boran, Genç, Kurt, and Akay, 2009; Olson, 2004; Zolfani and Antucheviciene, 2012), VIKOR(Chiu, Tzeng, and Li, 2013; Opricovic and Tzeng, 2007; Sayadi, Heydari, and Shahanaghi, 2009), DEMATEL(Chiu *etal*., 2013), PROMETHEE(Parreiras, Maciel, and Vasconcelos, 2006; Tomić, Marinković, and Janošević, 2011; Zhaoxu and Min, 2010), COPRAS-G (Chatterjee & Chakraborty, 2012)etc.

The detailed theory behind TOPSIS method is explained in the next section. From the literature study it reveals that there exist a research gap in selecting an optimal team for doing projects which needs to be identified and solved with the help of decision making methods. As a process of throwing light to the issue, in this research work we develop a HDMM which integrates the two dominant AHP and TOPSIS methods from the legacy and modern philosophical schemes.

3. PROPOSED METHODOLOGY

3.1 An Overview on two fold hybrid decision making model(HDMM)

The proposed two fold hybrid DMM is a research model depicted in Figure-1 which consists of three legacy process phases. They are the input phase, process/DM phase and the response phase. All these three phases constitute the overall HDMM. These three phases consist of sub phases which serve as the instance of the broad domain (three phases). The HDMM model begins with the input phase which consists of the source data for making an optimal decision. The phase initially gets the raw set of data through questionnaires that are answered by the personnel. These raw data are then formulated into a decision matrix as shown in Table-1. Here initial fitness values are qualitative in nature. Based on the DMs intuitive preference mechanism, these values are quantified. Triangular fuzzy numbers were deployed for the process of converting fitness values. Scores of these numbers were taken and a decision matrix with aggregated normal data is framed. The DM is also requested for framing an pair wise comparison matrix of the set of criteria.

The second phase of the HDMM is the process phase which is considered as the central hub of the proposed model. The process phase consists of two dominant ranking schemes hybridized to solve the TSP. In this hybridization mechanism we take advantage of the two methods by using AHP as a weighting factor and TOPSIS as a

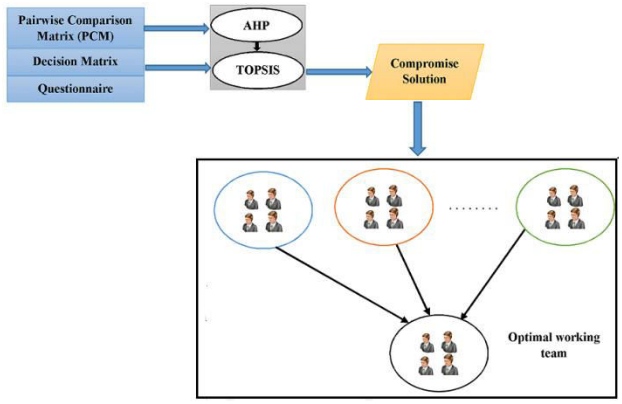

Figure-1. Hybrid decision making model.

ranking factor. We also validate the HDMM with other state of the art schemes. The variants like the normal TOPSIS, interval TOPSIS and Fuzzy TOPSIS are used as the competing partners of the proposed HDMM. The final phase is the response phase where the preference order along with the optimal compromise solution is elected. With respect to the research, the optimal team is selected for doing the project. The theoretic aspects of the two ranking schemes are given the next section.

3.2 An overview on AHP method

The AHP method is a legacy method proposed by Satty for ranking(Saaty, 2008; Satty T L, 1990). The method uses the concept of weights to rank the alternatives. The construction of the decision matrix is done using pairwise comparison. The hierarchical structure is most important of AHP method. This structure is viewed as an inverted tree with a suggestion from

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Sattythat; the process has to begin from goal and expand through various alternatives pertaining to different competing criteria. Several researchers have found variants of AHP. Some of the highlighted variants are the interval AHP(Entani, 2009), Fuzzy AHP(Kong and Liu, 2005), new scales AHP(Harker P T and Vergas L G, 1987; Saaty, 1977, 1980), Best Worst Method (BWM)(Rezaei, 2015) etc.

The pseudo code for AHP ranking method is given below:

Step 1: Construct a decision matrix with a well defined hierarchical structure. This structure includes the attribute, alternative, sub criteria etc.

Step 2: Collect data as per the guidance of experts and DM. These are qualitative measures of pair wise comparisons of entities. There are several metrics used by researchers to quantify the qualitative terms. Some of the popular quantification methods are nine likertscale (standard), As mentioned above the scales for metric quantification is done either using crisp or fuzzy scale sets (Harker P T and Vergas L G, 1987; Lou, 2016).

Table-2. Measurement scales for quantification.

Metric	Scale
Somewhat strong (SS)	3
Strong (S)	5
Equal (E)	1
Very strong (VS)	7
Extremely strong (ES)	9
Intermediate values	2,4,6,8
Consistency preservation policy	Follow triangle law of reciprocals

In this paper we adopt the standard quantification scale as shown in Table-2. Though there are other sophisticated scales proposed by researchers, the old school method is the simplest of them all and so we apply that scaling mechanism in our research.

Step 3: The fitness value with respect to the pair wise comparison is tabulated with the diagonal values being unity. We formulate an upper triangular matrix with the lower part being the reciprocals. Such a square matrix preserves consistency.

Step 4: Estimate the eigen value and eigen vector. These eigen vectors are normalized and it gives the weight of the alternatives. Ranking is done based on these weight values.

$$E_{value} = (A - \lambda I) \quad (1)$$
$$E_{vector} = (A - \lambda I)X \quad (2)$$

where A is the covariance matrix, I is the identity matrix and the X is the column matrix that deals with the response variable.

Step 5: Calculate the consistency values of the matrix. If the value is not plausible then reconsideration of the comparison fit is recommended. The consistency index is given by equation 3.

$$CI = {(\lambda_{max} - n)}/{(n-1)} \quad (3)$$

where the λ_{max} is the maximum eigen value of the judgement and n is the number of elements under consideration. Satty proposed a ration index RI and stated that the CI/RI must be less than 0.1 for maintaining consistency.

In this research work we maintain consistency using the standard scales metric and also find the weights for the criteria based on pair wise comparison of each criterion with others. These values are given by the DMs and thus the weights of the criteria are identified and are fed as input to the TOPSIS method. We discuss the details of TOPSIS method in our next section.

3.3 An overview on TOPSIS method

TOPSIS is a powerful ranking method that uses the idea of splitting the attribute as positives and negatives. Some researchers term this categorization as benefit and cost. Using these attributes the positive and negative ideal solution is estimated (PIS and NIS). Researchers have found several variants of TOPSIS methods. Some of the popular variants are fuzzy TOPSIS(Madi and Md. Tap, 2011), Interval TOPSIS(Dymova, Sevastjanov, and Tikhonenko, 2013), hybrid TOPSIS(Zolfani and Antucheviciene, 2012)etc. In our study we adopt TOPSIS method to deal with uncertain criteria. This method is integrated with the AHP for better efficiency in decision making.The steps involved in TOPSIS method are given below:

Step 1: Construct a decision matrix as shown in Table-1. Split the attributes into cost/benefit category. This splitting needs logical understanding of the module and domain. Generally decision makers split the criteria as cost and benefit. The cost set of attributes are generally minimized and the benefit set of attributes are generally maximized.

Step 2: Normalize the fitness value corresponding to each alternative using equation 4

$$Normalized\ fitness\ f_{ij}^{*} = {f_{ij}}/{\sqrt{\sum_{i=1}^{m} f_{ij}^{2}}} \quad (4)$$

where f is the fitness value of the alternative

Step 3: Calculate the weighted normalized fitness using equation (5) to construct a decision matrix of weighted normalized fitness values.

$$Weighted\ normalized\ fitness\ matrix\ \tau = \left(w_j f_{ij}^*\right) \quad (5)$$

where$\sum w_j = 1$ and the weight rangers from $0 \leq w \leq 1$, the DM decides the weight values for the criteria based on the domain knowledge. Here we propose a novel weighting mechanism using AHP.

Step 4: Estimate the best and worst alternatives using equations (6) and (7)

$$A_{worst} = \vee_{cost}\left(\tau_{ij}\right) \text{or} \wedge_{benefit}\left(\tau_{ij}\right) \quad (6)$$

$$A_{best} = \vee_{benefit}\left(\tau_{ij}\right) \text{ or } \wedge_{cost}\left(\tau_{ij}\right) \quad (7)$$

where$\wedge$ is the minimization operator, $\vee$ maximization operator and τ_{ij} is the instance of the weighed matrix.

Step 5: Estimate the L_2 distance metric using (8) and (9)

$$d_{worst} = \sqrt{\sum_{j=1}^{n}\left(\tau_{ij} - \tau_{wj}\right)^2} \quad (8)$$

$$d_{best} = \sqrt{\sum_{j=1}^{n}\left(\tau_{ij} - \tau_{bj}\right)^2} \quad (9)$$

whereτ_{bj} is the best weighted normal value and τ_{wj} is the worst weighted normal value.

Step 6: Determine the worst condition similarity index

$$s_{iw} = {d_{worst}}\Big/{(d_{best} + d_{worst})} \quad (10)$$

wheres_{iw} is 0 if the worst condition is considered and 1 if the best condition is considered. The similarity index is within the range [0,1].

Step 7: Rank the alternatives based on the similarity index measure. The lower the index value the lower is the rank priority.

4. RESULTS AND DISCUSSIONS

The proposed model is a hybrid model that uses the AHP and the TOPSIS method. The model takes advantage of the two dominant ranking methods. To understand the efficacy of the model, it is tested with a real time TSP. There are four criteria and three alternatives. Each of these three alternatives consist of four members for performing the life cycle development process namely; Analysis- Framing the Software Requirement Specification (SRS); Design- Constructing a prototype of the working model, iterate and refine to obtain the final product, Implement- Developing the working code for the product and Testing- Identify and rectify bugs to improve the performance and quality of the product.

The alternatives are termed as A = [A_1, A_2, A_3] and criteria as C=[C_1, C_2, C_3, C_4]. The decision matrix is formulated as shown in Table-1. The four criteria are Skill, Experience, Communication, Past Success Rate (PSR). The TSP is a MCDM problem that involves many criteria for analysis. Researchers have identified different valuable criteria for analysis (Dursun and Karsak, 2010; Zavadskas, Turskis, Tamošaitiene, and Marina, 2008; Zolfani and Antucheviciene, 2012). In this research we consider the most dominant traits which are pertaining with the in-house development process. The qualitative fitness values are transformed to its respective triangular fuzzy number and the score of these numbers are calculated to find the overall fitness rate of an alternative with respect to a criterion.

Table-3. Criteria pairwise comparison matrix.

Criteria relation	C_1	C_2	C_3	C_4
C_1	1	2	5	4
C_2	1/2	1	3	2
C_3	1/5	1/3	1	5
C_4	1/4	1/2	1/5	1

A square matrix relating to the criteria assessment by the DM is framed as shown Table-3. AHP is applied over this square matrix to obtain the weight values of the criteria as shown in Table-4. Based on these weighting measure alternatives are ranked using the TOPSIS ranking scheme. The preference order is compared with the other preference orders of different state of the art methods to obtain an effective decision. The voting by majority principle is adopted to determine the optimal preference sequence. The Table 5-8 depicts the investigation process in detail.

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Table-4. Estimation of criteria weights.

Criteria weight estimates	C_1	C_2	C_3	C_4
Weights (in %)	50.4	26.4	15.2	8
Rankings	1	2	3	4
Satty consistency value = 0.20				
Koczkodaj consistency value = 0.87				

Table-5. Triangular Fuzzy value of work groups.

Decision matrix	C_1	C_2	C_3	C_4
A_1	[0.24, 0.31, 0.31]	[0.3, 0.4, 0.4]	[0.2, 0.2, 0.3]	[0.2, 0.3, 0.4]
A_2	[0.26, 0.32, 0.35]	[0.2, 0.2, 0.3]	[0.2, 0.2, 0.3]	[0.12, 0.2, 0.3]
A_3	[0.16, 0.22, 0.3]	[0.2, 0.3, 0.4]	[0.2, 0.3, 0.3]	[0.3, 0.3, 0.4]

The Table-5 depicts the fitness value pertaining to each alternative over a specific criterion in the form of triangular fuzzy normalized numbers. The qualitative judgment by the DMs are aggregated and then normalized to make a dimensionless decision matrix for evaluation. The score value for each fitness instance is estimated and is shown in Table-6. The Table-7 depicts the preference order of the set of alternatives based on different weighting factors.

Table-6. Fitness score of work group.

Scoring matrix	C_1	C_2	C_3	C_4
A_1	0.29	0.37	0.23	0.3
A_2	0.31	0.23	0.23	0.27
A_3	0.3	0.3	0.27	0.33

Table-7. Rank analysis for different weights.

Ranking scheme	A_1	A_2	A_3
Score (W=AHP)	0.396	0.754	0.266
Ranking	2	1	3
Score (W=1/4)	0.329	0.633	0.433
Ranking	3	1	2

Table-8. Preference analysis of different schemes.

Preference order estimates	**TOPSIS**	**Fuzzy-TOPSIS**	**Interval-TOPSIS**	**HDMM (Proposed)**
A_1	2,2	3,2	3,2	3,2
A_2	1,1	1,1	1,1	1,1
A_3	3,3	2,3	2,3	2,3

It is clear from Table-8 that the preference order that is elected as an optimal compromise solution is$A_2 \succ A_3 \succ A_1$ when W is unbiased and $A_2 \succ A_1 \succ A_3$ when W is AHP. The vote by majority principle is adopted to choose a winning sequence.

5. CONCLUSIONS

The decision making is a rigorous process that involves different formal approaches and rational thinking. In this research work a novel two way hybrid DMM is proposed which performs well in the process of rational decision making. It hybridizes the two powerful ranking schemes namely AHP and TOPSIS to obtain a reasonable decision. The advantage of the proposed model is that it is (i) Easy to implement, (ii) Learns faster, (iii) Provides rational decision making framework at critical time. Its limitations are (i) Time consuming and (ii) Computationally complex. The future scope for the research is to use different attribute set and different ranking schemes for obtaining an optimal decision.

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Appendix

In this research work we have a newer dimension to TSP by not selecting personnel rather by selecting teams as a whole. This depicts the real time scenario more closely than the previous state of the art literature works. Here we chose four dominant attributes for evaluation of the alternatives namely, Skill, Experience, Communication and PSR. With the experts' advice and intuition from learning, these attributes are categorized as cost factors or benefit factors. The cost factors signify that the attribute has to be minimized and has a negative effect on the system. Whereas, positive attributes have positive effect on the system and they are to be maximized. The attribute description is given below:

- **Skill:** This attribute is an essential parameter of team formation. Any team selected for the project must fulfill the pre-requistite of being skillfully equipped. This parameter is considered as a benefit factor.
- **Experience:** This criterion is another competing factor for alternative selection. Expert based suggestion is that the greater the experience the smaller the synergy process. So we consider experience as a cost factor.
- **Communication:** This is a dominant attribute with respect to effecting teaming. Experts suggest that the effective communication can enhance team work and team spirit thereby improving the project's quality.
- **PSR:** The past success rate is another competing attribute. According to the experts, PSR is a challenging factor in team formation. It is sometimes a positive factor while some times a negative factor. Here, based on our intuition we chose PSR as a negative factor and categorized it as cost parameter.

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