ISSN(Online): 2320-9801
ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering
(A High Impact Factor, Monthly, Peer Reviewed Journal)
Website: www.ijircce.com
Vol. 6, Issue 1, January 2018

An Integrated Fuzzy ANP and TOPSIS Methodology for Software Selection under MCDM Perspective

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ABSTRACT: Information technology has unprecedented growth in today's competitive business and day to day life and has dramatic effects on various aspects of the performance of organizations. The role of engineering economics is to assess the appropriateness of a given project, estimate its value, and justify it from an engineering standpoint. Hence from business point of view software project selection is an important issue for many organizations. A business can be adversely and costly affected due the selection of a wrong software package as it cannot balance between the input investments and the expected output. In this project we propose to utilize analytical network process (ANP) on fuzzy set theory to calculate the weights of different criteria and evaluate the degree of interdependence between them. The fuzzy ANP is the fuzzy extension of ANP to efficiently handle the fuzziness of the data involved in the decision making. Then it is aimed to integrate fuzzy ANP with Technique for Order Preference Similarity to Ideal Solution (TOPSIS) algorithm to support project decisions and rank the alternatives in a preferred order to select the best one from a number of alternatives

KEYWORDS: ANP, TOPSIS, Software Selection, AHP

I. INTRODUCTION

To evaluate and select software packages that will fulfill the organization's requirement is a difficult software engineering process. As Information Technology plays a vital role in the success or failure of a business organization hence software project selection methodology becomes an integral part for many organizations from business point of view. Software selection is one of the most important decision making issues covering both qualitative and quantitative factors for organizations.

Importance of software selection in organizational perspective: Software selection is a method concerned with the process, methods and tools applied by organizations in order to decide which software should be chosen from the wide range of available solutions on the market.

Effects of inappropriate software selection in an organization: Software selection plays a vital role for the growth of an organization. Selecting the most appropriate software is a necessary condition for a successful implementation. Such a decision must be taken very carefully, as the adoption of software solutions is having an important impact in the medium for long term. This impact is not only related to purchase and operating costs, but also to the way the software is helping the company to build competitive advantage. **Anil S. Jadhav and Rajendra M. Sonar (2009)** highlighted the fact that improper selection of a software package may result in wrong strategic decisions with subsequent economic loss to the organization. The financial risk involved in the selection of inappropriate software is high, considering the fact that acquisition of software is a very high expense activity that consumes a significant portion of capital budgets[7].

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II. LITERATURE REVIEW

Chun-Chin Wei, Chen-Fu Chien, Mao-Jiun, and Wang (2004) presented a framework for selecting a suitable ERP system based on AHP decision analysis and the frame work offered the advantage of consistent structure of objectives, decomposing complex ERP selection problem into smaller ones and the flexibility to incorporate new attributes [1]. **Wei-Wen Wu** in his research (2008) proposed an effective solution for software selection using a hybrid approach by combining three MCDM methods-DEMATEL, ANP and ZOGP [3].**Ceyda Gungor Sen. ET. Al** (2009) described a hierarchical objective structure that contains both qualitative and quantitative objectives are used to evaluate software products systematically. This approach uses a heuristic algorithm, a fuzzy multi-criteria decision making procedure and a multi objective programming model to make final selection decision [7]. **Anil S. Jadhav** investigated methodologies for selecting software packages, evaluation techniques by using AHP, feature analysis, weighted sum average, expert system and fuzzy based approaches in their paper in 2009 **[**8]**. Arilo Claudio Dias-Neto and Guillermo Horta Travassos** (2010) proposed a strategy to select model-based testing approaches for software projects called Porantim. Porantim is based on a body of knowledge describing model-based testing approaches and their characterization attributes and a process to guide by adequacy and impact criteria regarding the use of this sort of software technology that can be used by software engineers to select model-based testing approaches for software projects.

III. OBJECTIVE

Since inappropriate selection of software can adversely affect the growth of an organization, hence it is very important and challenging for an organization to select a suitable software system that meets the need and requirements of an organization in an accepted way. Many complex decision problems cannot be structured hierarchically when the interaction of higher level elements with lower level elements and their dependency should be taken into account .The objective of this paper is

i) Identification of necessary criteria and evaluating attributes for vendor selection.
ii) Recognition of the interdependence between criteria.
iii) Calculating the weights of criteria using ANP by applying fuzzy concepts.
iv) Evaluating the rank of each alternatives and arrange them in a scale using TOPSIS.
v) Sensitivity analysis.
vi) Selection of optimal software.

IV. METHODOLOGIES USED

a) Fuzzy Analytical network process (FANP):

Fuzzy multi-criteria decision making (FMCDM) methods had been developed owing to the imprecision in assessing the relative importance of attributes and the performance ratings of alternatives with respect to attributes. Imprecision may arise from a variety of reasons: unquantifiable information, incomplete information, unobtainable information and partial ignorance. Conventional MCDM methods cannot effectively handle problems with such imprecise information. To resolve this difficulty, fuzzy set theory, first introduced by Zadeh (1965), has been popularly used and is adopted herein. Fuzzy set theory attempts to select, prioritize or rank a finite number of courses of action by evaluating a group of predetermined criteria. Solving this problem thus requires constructing an evaluation procedure to rate and rank, in order of preference, the set of alternatives.

This process of FANP comprises four major steps as follows:

Step 1: Establish model and problem
Step 2: Establish the Triangular Fuzzy Numbers
Step3: Establish the Fuzzy Pair-wise Comparison Matrix (independent and interdependent)
Step 4: Determine Eigen vectors and Super matrix Formation
Step 5: Evaluate the Decision

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b) Technique for Order Preference Similarity to Ideal Solution (TOPSIS)

TOPSIS is a useful technique in the field of multi criteria decision management. The fundamental principle of the method is that the selected alternative should have the shortest distance from Positive Ideal Solution(PIS) and the farthest distance from Negative Ideal Solution. Suppose multi criteria decision system having m alternatives and n decision criteria then the decision matrix is presented by [Xij] m x n. where Xij is the numerical outcomes obtained from ith alternative with respect to jth criteria.

Step-1: Construct the normalized decision matrix
Step-2: Calculate weighted normalized decision matrix
Step-3: Determine ideal and negative ideal solution.
Step-4: Calculate the separation measure for each alternative

V. VALIDATION OF PROPOSED MODEL

Numerical Application of Proposed Model:

Let us consider in this section a hypothetical case study for the validation of proposed model by following all step wise approaches. As an assumption, the criteria like security, reliability, user friendly, and maintenance are considered as identified criteria decided by the decision making team for software selection. All the shortlisted software's are roughly named as SOFT1, SOFT2, SOFT3, and SOFT4. Roughly their costs are taken as 600(USD), 625(USD), 695(USD), 620(USD). Table-1 represents Saaty's nine points scale. Based on Saaty's nine points rating scale, pair wise comparison matrix is formed by various experts considering horizontal alternatives versus vertical alternatives.

Level of satisfaction	**Rating**
Extremely preferred	9
Very strongly preferred	7
Strongly preferred	5
Moderately preferred	3
Equally preferred	1
Intermediate judgment between two adjacent judgment	2,6,4,8

Table 1 : Saaty's Nine Point Scale

Pair wise comparison matrix of Expert 1

	S	**R**	**UF**	**M**
S	1	3	1	1/2
R	1/3	1	1	1/3
UF	1/3	1	1	1/4
M	2	3	4	1

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Pairwise comparison matrix of Expert 2

	S	R	UF	M
S	1	1	4	1/2
R	1	1	3	1/2
UF	1/4	1/3	1	1/4
M	2	2	4	1

Pairwise comparison matrix of Expert 3

	S	R	UF	M
S	1	3	4	1
R	1/3	1	2	1/2
UF	1/4	½	1	1/4
M	1	2	4	1

Fuzzy triangular matrix of criteria

	S	R	UF	M
S	(1, 1, 1)	(1, 3, 3)	(1, 4, 4)	(1/3, √1/6, 1/2)
R	(1, 1/3, 1/3)	(1, 1, 1)	(1, 3, 3)	(1/3, √1/2, 1/2)
UF	(1, 1/4, 1/4)	(1, 1/3, 1/3)	(1, 1, 1)	(1/3, 1/2, 1/2)
M	(3,1/√1/6, 2)	(3, 1/√1/2, 2)	(3, 2, 2)	(1, 1, 1)

Now we get the pairwise comparison matrix of the goal with respect to the criteria by taking the average of each element in the fuzzy triangular matrix. Similarly we can find all the pairwise comparison matrix between the clusters which are dependent on each other

1. **With respect to Goal**

	S	R	UF	M	EV
S	1	2	3	1/2	0.277
R	1/2	1	2	1/3	0.161
UF	1/3	1/2	1	1/4	0.096
M	2	3	4	1	0.466
					CR=0.0006

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2. With respect to Security

	R	UF	M	EV
R	1	2	1/3	0.239
UF	1/2	1	1/4	0.137
M	3	4	1	0.623
				CR=0.016

3. With respect to Reliability

	S	UF	M	EV
S	1	3	1/2	0.320
UF	1/3	1	1/4	0.123
M	1/3	1	1/4	0.123
				CR=0.020

4. With respect to User friendly

	S	R	M	EV
S	1	2	1/2	0.297
R	1/2	1	1/3	0.163
M	2	3	1	0.539
				CR=0.0033

5. With respect to Maintenance

	S	R	UF	EV
S	1	2	3	0.539
R	1/2	1	2	0.297
UF	1/3	1/2	1	0.164
				CR=0.0090

6. With respect to Security

	S1	S2	S3	S4	EV
S1	1	9	8	3	0.557
S2	1/9	1	1/6	1/9	0.036
S3	1/8	6	1	1/6	0.106
S4	1/3	9	6	1	0.300
					CR= 0.245

ISSN(Online): 2320-9801
ISSN (Print) : 2320-9798

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7. With respect to Reliability

	S1	S2	S3	S4	EV
S1	1	6	4	8	0.590
S2	1/6	1	1/3	3	0.117
S3	1/4	3	1	5	0.238
S4	1/8	1/3	1/5	1	0.052
					CR= 0.081

8. With respect to User friendly

	S1	S2	S3	S4	EV
S1	1	3	5	3	0.519
S2	1/3	1	3	1	0.201
S3	1/5	1/3	1	1/3	0.790
S4	1/3	1	3	1	0.200
					CR= 0.020

9. With respect to Maintenance

	S1	S2	S3	S4	EV
S1	1	1/4	1	1/5	0.089
S2	4	1	4	1/2	0.319
S3	1	1/4	1	1/5	0.089
S4	5	2	5	1	0.501
					CR=0.009

10. With respect to Soft 1

	S	R	UF	M	EV
S	1	2	4	8	0.466
R	1/2	1	3	7	0.320
UF	1/4	1/3	1	5	0.157
M	1/8	1/7	1/5	1	0.041
					CR=0.020

11. With respect to Soft 2

	S	R	UF	M	EV
S	1	1/7	1/8	1/9	0.038
R	7	1	1/2	1/3	0.188
UF	8	2	1	1/2	0.294
M	9	3	2	1	0.478
					CR=0.0429

ISSN(Online): 2320-9801
ISSN (Print) : 2320-9798

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12. With respect to Soft 3

	S	R	UF	M	EV
S	1	1/4	1	1	0.143
R	4	1	4	4	0.571
UF	1	1/4	1	1	0.143
M	1	1/4	1	1	0.443
					CR= 0.008

13. With respect to Soft 4

	S	R	UF	M	EV
S	1	7	4	2	0.493
R	1/7	1	1/4	1/6	0.052
UF	1/4	4	1	1/3	0.142
M	1/2	6	3	1	0.311
					CR=0.0488

Cluster node labels		Selection	Criteria				Alternatives			
			S	R	UF	M	S1	S2	S3	S4
Selection	**Selection**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Criteria	S	0.28	0.00	0.32	0.30	0.54	0.47	0.04	0.14	0.50
	R	0.16	0.24	0.00	0.16	0.30	0.33	0.19	0.57	0.05
	UF	0.10	0.14	0.12	0.00	0.16	0.16	0.30	0.14	0.14
	M	0.46	0.63	0.56	0.54	0.00	0.04	0.48	0.14	0.31
Alternatives	S1	0.00	0.57	0.60	0.52	0.09	0.00	0.00	0.00	0.00
	S2	0.00	0.03	0.11	0.19	0.32	0.00	0.00	0.00	0.00
	S3	0.00	0.09	0.23	0.08	0.09	0.00	0.00	0.00	0.00
	S4	0.00	0.30	0.05	0.19	0.50	0.00	0.00	0.00	0.00

Table 2: Super matrix of the ANP model

Since four criteria's are considered for selection purpose and the summation of weights of these criteria's need to be equal to 1, hence ideally the expected weight of each criterion should be equal to 0.25. However from the super matrix of the analytical network process the weights of each of the criteria are obtained as $W_{security}$=0.28, $W_{reliability}$=0.16, $W_{userfriendly}$=0.10 and $W_{maintenance}$=0.46. So, by applying Chi square test it should be checked whether the observed weights are within a certain range of accuracy or not.

Criteria	Observed(O)	Expected(E)	O-E	$(O-E)^2$	$(O-E)^2/E$
Security(S)	0.28	0.25	0.3	0.09	0.36
Reliability(R)	0.16	0.25	- 0.9	0.81	3.24
User Friendly(UF)	0.10	0.25	- 0.15	0.0225	0.09
Maintenance(M)	0.46	0.25	- 0.21	0.0441	0.1764
$\chi^2 = \sum(O-E)^2/E = 3.8664$					

Table 3: Calculation of Chi square

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Here Degree of freedom is 3 and we consider $\alpha = 0.05$. From the standard Chi square table it is seen that $\chi^2_{3,\,0.05} = 7.28$. Since the calculated $\chi^2 < \chi^2_{3,\,0.05}$, therefore it is considered that the observed weights can be accepted.

Now these weights are given as input to the TOPSIS model and the final ranking of the alternatives are done. Therefore the decision matrix (D) is shown below:

	S	R	UF	M
D=	9	2	3	2
	3	7	4	6
	3	2	8	4
	2	3	7	4

Then the normalized decision matrix(R) is constructed as $r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$ (4.1), where i= 1, 2…….4; j=1, 2… 3; where, r_{ij} is the element of the matrix. This normalized matrix is shown

$$R = \begin{bmatrix} 0.886 & 0.246 & 0.255 & 0.236 \\ 0.295 & 0.862 & 0.341 & 0.325 \\ 0.295 & 0.246 & 0.681 & 0.471 \\ 0.197 & 0.369 & 0.596 & 0.471 \end{bmatrix}$$

Then weighted normalized matrix (V) is calculated by multiplying each column of the matrix R with its associated weight Wj. Each element in V will be represented as

$$V_{ij} = r_{ij} \text{ x } W_j$$

$$V = \begin{bmatrix} 0.248303 & 0.039389 & 0.025538 & 0.108423 \\ 0.082768 & 0.137862 & 0.034050 & 0.325269 \\ 0.082768 & 0.039389 & 0.068101 & 0.216846 \\ 0.055178 & 0.059084 & 0.059588 & 0.216846 \end{bmatrix}$$

As per Step-3 and Step-4 mentioned in the TOPSIS section, the ideal and negative ideal solutions are calculated and with these values and the separation between each alternative is measured by n-dimensional Euclidian distance. The alternative that is nearest from PIS and farthest from NIS is considered to be the optimal one. The separation measure from PIS (S_i^+) and NIS (S_i^-)are given below in table 6 and table 7 respectively.

S_1^+	0.220920
S_2^+	0.043824
S_3^+	0.102265
S_4^+	0.079237

Table 4: Separation measure S_i^+ of each alternative from PIS

ISSN(Online): 2320-9801
ISSN (Print) : 2320-9798

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S_1^-	0.200330
S_2^-	0.288928
S_3^-	0.169438
S_4^-	0.166384

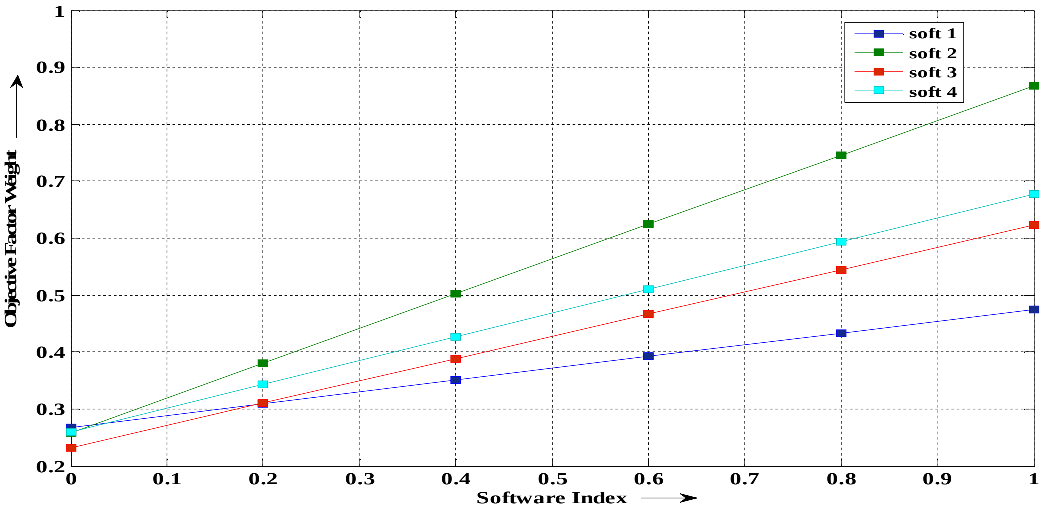
Table 5: Separation measure S_i^- of each alternative NIS

Then relative closeness to the ideal solution is obtained as per Step-5 of TOPSIS section. Then all the software's are ranked in order of their relative closeness value from ideal and negative ideal solution. The relative closeness values are shown in the table 8 mentioned below.

Decision Alternatives	Closeness Index	Closeness values(score)
SOFT 1	C_1*	0.475561
SOFT 2	C_2*	0.868297
SOFT 3	C_3*	0.623615
SOFT 4	C_4*	0.677401

Table 6: Score of each decision alternative

From table 6 it is seen that SOFT 2 has the minimum distance from the positive ideal solution and maximum distance from negative ideal solution. Hence SOFT 2 has the highest score among all the alternatives.



VI. SUMMARY AND CONCLUSION

Literature survey reveals varieties of software selection models. In the current research, we proposed selection mechanism in a different way where not only focus is on mentioned features; rather we form ranking among all. Secondly, the hybrid approach of FANP/TOSIS in the proposed model takes the concept that the alternatives are

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ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

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Vol. 6, Issue 1, January 2018

close to the positive ideal solution and away from the negative ideal solution into account. The methodology presents a more accurate mode for eliciting the preferences of decision makers The proposed model not only considers the interdependence and feedback between various clusters but also tries to remove the ambiguities and vagueness related to any decision using the fuzzy concept. Finally, sensitivity analysis of the proposed model is done to provide the decision maker a robust decision support system to evaluate the performance of the software's.

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