FUZZY TOPSIS APPROACH TO IMPROVE QUANTITATIVE RISK ANALYSIS CONSIDERING DIFFERENT CRITERIA AND THEIR MUTUAL EFFECTS

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Abstract: In PMBOK, a widely used project management standard, different risks are ranked based on two criteria: their probability and their impact on the project objectives. The multiplication of these two criteria is considered as the index of ranking the risks. This index ignores other criteria and also works weak in some special situations. In addition, it seems ambiguous when an expert is asked to determine the impact of risks on the project objectives via only one variable. This paper proposes a fuzzy multi-criteria approach to effectively analyze the impact of the risks on different important aspects of a project. The proposed approach works in a fuzzy environment with linguistic variables. The concept of linguistic variable is very useful in situations where decision problems are too complex or too ill-defined to be described properly using conventional quantitative expressions. Finally, the proposed approach is performed in a case study and the results have been compared with a deterministic TOPSIS method; which shows a significant difference in rankings when the fuzziness has been incorporated in the risk analysis process.

1 INTRODUCTION

Projects have strategic, technical, economical and national elements and reaching to their defined targets will face with threats and opportunities that affect critical objectives of project like schedule, cost, and quality. The root of these threats and opportunities can be found in the set of non-deterministic conditions or uncertainties that occur as a result of technical, managerial, commercial, internal and external issues. Project risk is defined as uncertain event or condition that will result positive or negative impact on the project objectives, if happens (Konstantinos, 2002).

Risk management is the systematic process of identifying, analyzing, and responding to project risks. It includes maximizing the probability and the consequences of positive events and minimizing the probability and the consequences of adverse events towards project objectives.

Some guides, so called standards, exist for risk management, including: New Zealand and Australian standard AS/NZS4360, analysis and management guide of APM named PRAM, commercial risk management guide of England called M_O_R, and the most popular of them, presented by PMI institute called PMBOK standard (PMI, 2004). This standard proposes tools for qualitative and quantitative risk analysis.

In this paper, a fuzzy TOPSIS method is proposed to improve the qualitative risk analysis. The proposed approach is implemented in an oil and petrochemical company.

The rest of the paper is organized as follows. Section 2 briefly describes the risk management based on PMBOK standard. Section 3 explains the proposed approach for improving the risk analysis process. Section 4 shows the case study results and section 5 compares them with the results of a deterministic version of TOPSIS method.

2 QUALITATIVE RISK ANALYSIS

Regard to PMBOK (PMI, 2004) risks are prioritized and ranked using two factors: Risk probability, P, and impact on the project objectives, I. Then these

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risks are ranked using risk score, *R.S.*, index, where:

$$R.S. = P \times I \quad (1)$$

Then, a risk acceptance level will be determined and risks are classified into three groups including: high, moderate, and low important risks. Figure 1 is an example of probability-impact (PI) matrix to determine whether a risk is considered low, moderate, or high.

Probability (P)	Risk score=P*I				
0.9	0.05	0.09	0.18	0.36	0.72
0.7	0.04	0.07	0.14	0.28	0.56
0.5	0.03	0.05	0.10	0.20	0.40
0.3	0.02	0.03	0.06	0.12	0.24
0.1	0.01	0.01	0.02	0.04	0.08
Impact (I)	0.05	0.10	0.20	0.40	0.80

High importance
Moderate importance
Low importance

Figure 1: Probability-impact (PI) matrix.

In this method, risks that have high probability and high impact have higher priority. Some guides propose other criteria besides the risk probability and impact factor like: Capability of the company to respond to the risk (McDermott et al, 1996), uncertainty of estimation (Klein and Cork, 1998), or efficiency and swiftness to respond to the risks (Lambert et al, 2001). Using these criteria can remarkably help the risk management process.

In this paper, different criteria can be used in a fuzzy multi-criteria method. This procedure is explained in section 3.

3 PROPOSED APPROACH FOR IMPROVING RISK ANALYSIS

In this paper, we used a fuzzy TOPSIS method proposed by Chen (2000) for ranking the risks which improve the risk analysis in two aspects:

- Using risk score cannot comply the aim and outputs of risk analysis in reporting correct priority of risks. For example, some risks with high impact and low probability have low risk score. So that project face with serious problem if it happen even the probability is low. But, more criteria can be used in the proposed approach.
- In PI matrix, if two risks have the same risk score, will treated the same. But two risks with equal risk score never have same importance. Because probability scale and risk impact do not have same importance. But, in the proposed approach different weights can be considered in order to make the criteria different.

This way, multi-criteria decision-making methods in comparison with impact-probability method (PI matrix) are more efficient, regarding various criteria. One of these methods is fuzzy TOPSIS which considers the evaluation in a fuzzy area. In this approach, we consider four criteria and risks are ranked base on their impact on project objectives like: schedule, cost, quality, health, safety, and environment (HSE), and synergy factor. Because the most important criteria for risk ranking with every probability scale is effect of them on project objectives, also event probability is considered while identifying of risks and are omitted impossible risks (risks with zero probability) from risks list, therefore using impact criteria for risk ranking is sufficient. In addition, mentioned objectives are not independent but influence each other. Projects have some risks that make other major risk(s) however themselves have low impact on project objectives. There are other risks that influence major or important risks. The meaning of synergy is consideration of such risks.

4 CASE STUDY

The proposed approach has been implemented in an oil and petrochemical company.

After identification of major and important project risks, they are weighted according to fuzzy TOPSIS procedure. Table 1 shows linguistic variables used for implying the weight of each criterion.

Table 1: Linguistic variables for the importance weight of each criterion.

Linguistic value	Fuzzy Number
Very low (VL)	(0; 0; 0.1)
Low (L)	(0; 0.1,0.3)
Medium low (ML)	(0.1; 0.3; 0.5)
Medium (M)	(0.3; 0.5; 0.7)
Medium high (MH)	(0.5; 0.7; 0.9)
High (H)	(0.7; 0.9; 1)
Very high (VH)	(0.9; 1; 1)

Table 2 and 3 show the identified risks and their evaluations. Table 4 shows the rank of risks and three groups made based on the rankings. This way, the risks have been sorted based on their total score achieved by fuzzy TOPSIS; then the first 30% of the list have been reported as high-important risks, second 30% as medium important, and the remained as low important risks. Thus, the main attention will be paid to the high-important risks.

The next groups of risk will be taken into consideration if the required resources, i.e. money, time, and etc., are still available.

Table 2: Risk descriptions.

Code	description
R1	Uncompleted pilot and elaborative plan and disclosing their results in preparation of stuffs
R2	Correction of ASBUILT plan due to repugnance and operational limitations
R3	Uncompleted pilot and elaborative plan and disclosing their results in execution
R4	Natural condition of ground
R5	Sea storming and not to transfer equipment and materials to destination
R6	Low visibility due to existing of dust so not to transfer air and sea transports
R7	Rain fall
R8	Severe wind blowing
R9	Uncovering of inventory
R10	Scrimpy place of inventory
R11	Scrimpy safety of inventory
R12	Not permission by control room of employer
R13	Not regarding to permit principle and out breaking problems that threaten oil's bulk safety
R14	Resistance of employee against uninstalling old equipment and replacement new equipment
R15	Distance between hostage, office, and workshop
R16	Distance between workshop, operational place and road, accommodation
R17	Employee strike
R18	Learning of unskillful employee for repetitive works
R19	Employing of native worker
R20	Low quality of materials and stuffs
R21	Delay in delivering of concrete
R22	Mistake in selection of proper contractor
R23	Acceptation of high work burden more than capacity by contractor
R24	Hiring of expert contractor according to analyses
R25	Delay in accomplishment of project milestones
R26	Incorrect assessment of labor rate
R27	Not outfit workshop at the correct time
R28	Lack of the expert labor
R29	Weak assessment of labor and required expert
R30	Using night work shift
R31	Machines and equipment failure
R32	Changing executive specification due to not to be optimum
R33	Inaccuracy in financial statement accounting

5 COMPARING THE RESULTS WITH A DETERMINISTIC TOPSIS METHOD

In this section, we compare the results when a deterministic version of TOPSIS is implemented. To do so, we first defuzzified the evaluations presented in table 3 via a defuzzification method, so called the center of area, proposed by Zhao and Govind (1991). In this defuzzification method, if the triangular fuzzy number is $\widetilde{A} = (a_1, a_2, a_3)$; its deterministic value is calculated from equation 2:

$$A = \frac{(a3 - a1) + (a2 - a1)}{3} + a1 \qquad (2)$$

Then, a deterministic TOPSIS method is performed over this data which has been resulted in the rankings presented in table 5.

Comparing tables 4 and 5, a significant difference has been resulted when the uncertainty is incorporated in the risk analysis process.

Table 3: Evaluations of the identified risks.

	Schedule	Cost	Quality	H.S.E.	Synergy
w_i	(0.1,0.3,0.5)	(0.077,0.233,0.433)	(0.033,0.177,0.277)	(0.077,0.233,0.433)	(0,0.1,0.3)
R1	(3,5,7)	(2.33,4.33,6.33)	(0,1,3)	(0,1,3)	(3,5,7)
R2	(3,5,7)	(1,3,5)	(0,1,3)	(0,1,3)	(4.33,6.33,8.33)
R3	(4.33,6.33,8.33)	(3,5,7)	(1,3,5)	(0,1,3)	(5,7,9)
R4	(1,3,5)	(1,3,5)	(0,1,3)	(1,3,5)	(0.78,2.33,4.33)
R5	(2.33,4.33,6.33)	(3,5,7)	(0,1,3)	(0,1,3)	(0,1,3)
R6	(2.33,4.33,6.33)	(2.33,4.33,6.33)	(0,1,3)	(1,3,5)	(0,1,3)
R7	(4.33,6.33,8.33)	(3,5,7)	(1,3,5)	(4.33,6.33,8.33)	(0.78,2.33,4.33)
R8	(2.33,4.33,6.33)	(1,3,5)	(0,1,3)	(2.33,4.33,6.33)	(0.78,2.33,4.33)
R9	(0.78,2.33,4.33)	(1,3,5)	(1,3,5)	(1,3,5)	(0,1,3)
R10	(0,1,3)	(1,3,5)	(1,3,5)	(0,1,3)	(0,1,3)
R11	(1,3,5)	(5,7,9)	(0,1,3)	(3,5,7)	(0,1,3)
R12	(0.78,2.33,4.33)	(0.78,2.33,4.33)	(0,1,3)	(0,1,3)	(0,1,3)
R13	(2.33,4.33,6.33)	(1,3,5)	(0,1,3)	(7,9,10)	(4.33,6.33,8.33)
R14	(2.33,4.33,6.33)	(1,3,5)	(0,1,3)	(0,1,3)	(1,3,5)
R15	(2.33,4.33,6.33)	(1,3,5)	(0,1,3)	(0.78,2.33,4.33)	(0,1,3)
R16	(1,3,5)	(2.33,4.33,6.33)	(0,1,3)	(0,1,3)	(0,1,3)
R17	(5,7,9)	(3,5,7)	(0,1,3)	(0,1,3)	(2.33,4.33,6.33)
R18	(3,5,7)	(1,3,5)	(5,7,9)	(3,5,7)	(0.78,2.33,4.33)
R19	(5,7,9)	(5,7,9)	(0,1,3)	(0,1,3)	(1,3,5)
R20	(3,5,7)	(1,3,5)	(5,7,9)	(0,1,3)	(3,5,7)
R21	(1,3,5)	(0,1,3)	(0,1,3)	(0,1,3)	(3,5,7)
R22	(3,5,7)	(1,3,5)	(7,9,10)	(0,1,3)	(4.33,6.33,8.33)
R23	(7,9,10)	(5,7,9)	(3,5,7)	(0,1,3)	(3,5,7)
R24	(3,5,7)	(1,3,5)	(5,7,9)	(0,1,3)	(4.33,6.33,8.33)
R25	(7,9,10)	(1,3,5)	(1,3,5)	(0,1,3)	(5,7,9)
R26	(5,7,9)	(0,1,3)	(1,3,5)	(0,1,3)	(2.33,4.33,6.33)
R27	(5,7,9)	(1,3,5)	(0,1,3)	(0.78,2.33,4.33)	(1,3,5)
R28	(3,5,7)	(1,3,5)	(1,3,5)	(0,1,3)	(1,3,5)
R29	(3,5,7)	(0,1,3)	(3,5,7)	(0,1,3)	(2.33,4.33,6.33)
R30	(7,9,10)	(1,3,5)	(0,1,3)	(1,3,5)	(0,1,3)
R31	(5,7,9)	(3,5,7)	(0,1,3)	(0,1,3)	(0.78,2.33,4.33)
R32	(5,7,9)	(3,5,7)	(1,3,5)	(0,1,3)	(1,3,5)
R33	(0,1,3)	(7,9,10)	(0,1,3)	(0,1,3)	(0,1,3)

Table 4: Ranking and categorizing of the identified risks.

Total score	Risk code	Rank	Group
0.5821	R18	1	High
0.5773	R7	2	High
0.5741	R23	3	High
0.5681	R20	4	High
0.5678	R24	5	High
0.5673	R22	6	High
0.5647	R3	7	High
0.5636	R13	8	High
0.5616	R32	9	High
0.5579	R25	10	High
0.5527	R8	11	Medium
0.5513	R29	12	Medium
0.5501	R17	13	Medium
0.5497	R28	14	Medium
0.549	R1	15	Medium
0.547	R11	16	Medium
0.5468	R19	17	Medium
0.5445	R27	18	Medium
0.5407	R26	19	Medium
0.5398	R31	20	Medium
0.5391	R2	21	Low
0.5375	R6	22	Low
0.5337	R4	23	Low
0.5332	R30	24	Low
0.5294	R9	25	Low
0.5292	R14	26	Low
0.5197	R5	27	Low
0.517	R15	28	Low
0.511	R21	29	Low
0.5098	R16	30	Low
0.4958	R33	31	Low
0.4844	R10	32	Low
0.4723	R12	33	Low

This way, the imprecision and vagueness of evaluation measures has been considered.

Table 5: Ranking and categorizing of the defuzzified risks.

Risk	Score	Rank	Group
R7	0.793411	1	High
R18	0.737109	2	High
R13	0.626871	3	High
R11	0.578093	4	High
R8	0.569478	5	High
R23	0.545335	6	High
R6	0.52581	7	High
R9	0.525534	8	High
R3	0.513905	9	High
R27	0.511073	10	High
R4	0.508355	11	Medium
R22	0.496536	12	Medium
R32	0.495823	13	Medium
R24	0.492293	14	Medium
R30	0.490427	15	Medium
R20	0.487981	16	Medium
R25	0.464822	17	Medium
R19	0.457698	18	Medium
R15	0.452615	19	Medium
R17	0.446199	20	Medium
R28	0.437949	21	Low
R1	0.435378	22	Low
R31	0.427771	23	Low
R2	0.397198	24	Low
R5	0.39505	25	Low
R16	0.37233	26	Low
R14	0.369256	27	Low
R33	0.359939	28	Low
R29	0.334796	29	Low
R10	0.315488	30	Low
R26	0.300249	31	Low
R12	0.269112	32	Low
R21	0.224253	33	Low

6 CONCLUSIONS

In this paper, a new approach is proposed for improving risk analysis process. This approach use fuzzy TOPSIS method for ranking and prioritizing different risks of a typical project. The proposed approach has been implemented in a case study and used to categorize the identified risks. Finally, a comparison is provided when a deterministic version of TOPSIS is implemented over the case study data.

The proposed approach, compared with the conventional PI matrix, improves the risk analysis process in the following aspects:

- Using risk score cannot comply the aim and outputs of risk analysis in reporting correct priority of risks. For example, some risks with high impact and low probability have low risk score. So that project face with serious problem if it happen even the probability is low. But, more criteria can be used in the proposed approach.
- In PI matrix, if two risks have the same risk score, will treated the same. But two risks with equal risk score never have same importance. Because probability scale and risk impact do not have same importance. But, in the proposed approach different weights can be considered in order to make the criteria different.
- Using fuzzy and linguistic values help the users in describing the values in a more flexible language and to deal with the imprecision and vagueness of evaluation measures
- Definition of synergy factor in TOPSIS model and focusing on dependent risk(s) results in better risk response planning.

REFERENCES

Buckley, J. J., 1985. Fuzzy hierarchical analysis. *Fuzzy Sets and Systems*, 17, 233-247.

Chen, C. T., 2000. Extensions of the TOPSIS for group decision-making under fuzzy environment. *Fuzzy Sets and Systems*, 114 (1), 1-9.

http://www.apm.org.uk/pub/public.htm

http://www.broadleaf.com .au /services/proj_rm.htm

http://www.ogc.gov.uk

http://www.standards.com.au

Kaufmann, A., Gupta, M. M., 1991. *Introduction to Fuzzy Arithmetic*. Theory and Applications. New York, Van Nostrand-Reinhold.

Klein, J. H., Cork, R. B., 1998. An Approach to Technical Risk Assessment. *International Journal of Project Management*, 16(6), 345-351.

Konstantinos, K., 2002. Risk Management: A powerful tool for improving efficiency of project oriented SMEs. *Manufacturing Information Systems*.

Lambert, J. H., Haimes, Y. Y., Li, D., Schooff, R. M., Tulsiani, V., 2001. Identification, ranking, and management of risks in a major system acquisition. *Reliability Engineering and system Safety*, 72, 315-325.

McDermott, R. E., Mikulak. R. J., Beauregard. M. R., 1996. The Basics of FMEA. *Quality Resources*, 12.

PMI, 2004. *A Guide to the Project Management Body of Knowledge*. Project Management Institute Standards Committee, USA, 3rd edition.

Rezaie, K., Amalnik, M. S., Gereie, A., Ostadi, B., Shakhseniaee, M., 2007. Using extended Monte Carlo simulation method for the improvement of risk management: Consideration of relationships between uncertainties. *Applied Mathematics and Computation*, 190, 1492-1501.

Zhao, R., Govind, R., 1991. Algebraic characteristics of extended fuzzy numbers. *Information Sciences*, 54 (1-2), 103-130.