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Risk Evaluation of Information Technology Projects Based on Fuzzy Analytic Hierarchal Process

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Abstract**—**Information Technology (IT) projects are always accompanied by various risks and because of high rate of failure in such projects, managing risks in order to neutralize or at least decrease their effects on the success of the project is strongly essential. In this paper, fuzzy analytical hierarchy process (FAHP) is exploited as a means of risk evaluation methodology to prioritize and organize risk factors faced in IT projects. A real case of IT projects, a project of design and implementation of an integrated information system in a vehicle producing company in Iran is studied. Related risk factors are identified and then expert qualitative judgments about these factors are acquired. Translating these judgments to fuzzy numbers and using them as an input to FAHP, risk factors are then ranked and prioritized by FAHP in order to make project managers aware of more important risks and enable them to adopt suitable measures to deal with these highly devastative risks.

Keywords**—**Information technology projects, Risk evaluation, Analytic hierarchal process, fuzzy logic.

I. Introduction

NOWADAYS, corporations count on information technology as a core competence more than ever and huge investments of superior companies in information technology shows such increasing awareness in top managers [1]. High rate of failure in IT projects intensifies the need to adopt suitable measures to negate unfavorable effects of risk on such projects. Risk addresses the condition that is out of control of the project team and if it is not neutralized, it will cause adverse influence on the success of a project. Successful project managers try to solve the potential problems before they occur by using risk management tools. Chapman and Cooper define risk as “exposure to the possibility of economic or financial loss or gains, physical damage or injury or delay as a consequence of the uncertainly associated with pursuing a course of action” [2]. The American National Standard Institution defines project risk as “An uncertain event or condition that, if it occurs, has a positive or a negative effect on that least one project objective, such as time, cost, scope, or quality, which implies an uncertainly about identified events and conditions” [3]. Risk and uncertainly management use the following three-step approach:

1. Risk identification: the first step of risk management process is risk identification. It includes the recognition of potential sources of risk and uncertainty event conditions in the project and the clarification of risk and uncertainty responsibilities. It is accomplished by a structured search for a response to the question – what events may reasonably occur that will impede the achievement of key elements of the highway construction?
2. Risk assessment: risk and uncertainty rating identifies the importance of the sources of risk and uncertainty to the goals of the project. It comes as a response to the questions – what is the probability that this risk will occur? And what is the severity of the impact on the project if a risk is allowed to take place? Risk assessment is accomplished by estimating the probability of occurrence and severity of risk impact.
3. Risk mitigation: mitigation establishes a plan, which reduces or eliminates sources of risk and uncertainty impact to the project’s deployment. The question is – what should be done, and whose responsibility it is to eliminate or minimize the effect of risk and uncertainty? Options available for mitigation are: control, avoidance, or transfer.

Risk can be assessed by different criteria. In this paper, two criteria namely probability and risk severity (that is the degree at which the risk influences the project) are used to appraise the risk. Risk evaluation of the IT projects is a complicated process and in this process, identifying all factors leading to the project failure, considering the probability of their occurrence and their consequences are essential.

Risk management in IT projects can be divided into two sequent phases: risk evaluation and adopting effective measures [4]. The risk evaluation methodology focused on in this paper, consists of identification of risk factors related to IT projects and ranking them in order to make suitable decisions. Because of high degree of complexity in IT projects, time/cost estimation in such projects is accompanied by such hardly beatable difficulties that some IT projects (because of underestimation of cost/time) have failed or are forced to diminish project scope [5],[6]. Standish group in 2004 in a report called CHAOS declared that cost/time of about 53% of software development projects estimated in the beginning of the projects does not conform with realized cost/time and/or

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the project is delivered with not all the promised features and applications; and all that mean imposing noticeable risks to corporations [7].

In the risk evaluation literature in the IT field, different works has been done. Barki, *et al.* developed a methodology and a decision support tool to assess risks of software development projects [8]. Wallace, *et al*. determined six dimensions of risk in IT projects and proposed a reliable and valid framework to assess them [9]. Tüysüz and Kahraman evaluated risks of IT projects using fuzzy analytical hierarchy process [10]. Our contribution to the aforementioned paper is three folded: a different hierarchy structure is used here for the first time by considering two criteria of assessing risk i.e. risk severity and risk probability, a more comprehensive list of risk factors adopted from [11] is considered, and also a more reliable approach to deal with fuzzy sets is used here. Because the risk evaluation of the IT projects depends on the fundamental analysis based on the opinions, principles and experience of experts, in our case, opinions of six different experts are used to grade the fuzzy risk factors.

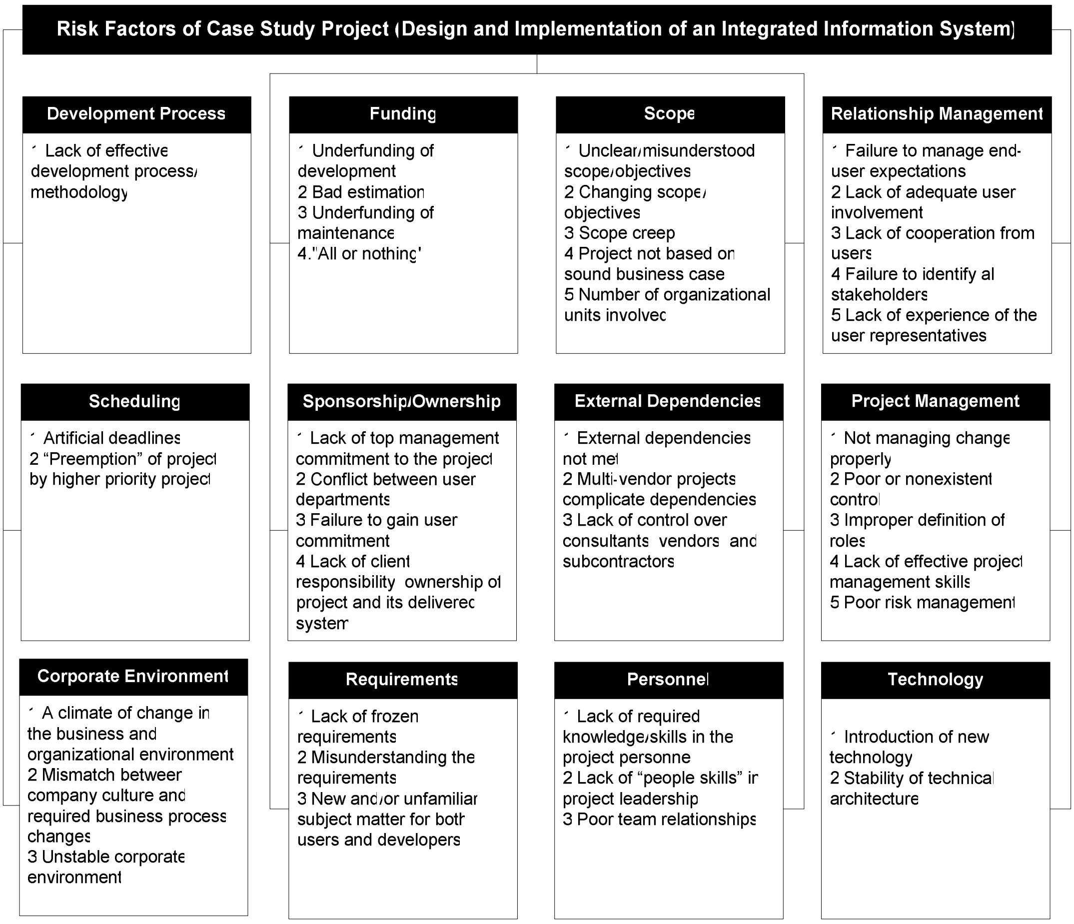

Fig. 1 Risk Factors of Case Study Project (Design and Implementation of an Integrated Information System)

II. Proposed Methodology

In this part, our methodology is described in the following sections that cover the first two steps of risk and uncertainly management approach proposed in [3].

A. Risk Identification of International Construction Projects

The first step in managing risks in IT projects, as well as any other projects, is identification of pertaining risks in order to control and counteract them [10]. Risk factors in projects can be viewed as threats to success of a project. Risk factors in IT world and software development are multi-dimensional and in spite of extensive studies and works of different researchers from 1981 till now, risk evaluation and assessment is still complex. In 1981, McFarlan proposed three dimensions of risk management in IT projects i.e. project size, technological experience and project structure and suggested that project managers make a comprehensive profile of risks related to IT projects [12]. In 1991 Boehm provided a check list of the 10 most important risks in IT projects by a filed study and interview with IT expert project managers [4]. Barki, *et al.* suggested 35 risk factors summed up in the following 5 categories: technological issues of the project, project size, personnel expertise, project complexities, and project environment [8]. In 2001, Klein classified 38 risk factors in BRP projects into 4 categories namely human factors, management, enterprise and technical aspects [13]. Schmidt, *et al.* in 2001 in a multi-national study, listed 53 risk factors in 14 categories by using Delphi technique [11]. Addison in 2003 proposed 28 risk factors, by using opinions of 32 IT project

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experts in e-commerce and other related projects by exploiting Delphi technique [14].

In this paper, Schmidt *et al.*'s list [10] (because of its comprehensiveness) is used as a reference model and 12 risk factors that make sense and are relevant to the real case selected here to study are opted. In Fig. 1, the 12 risk factors related to a project of design and implementation of an integrated information system in a vehicle producing company in Iran is illustrated.

Key risk factors determine the levels of analytical hierarchy process (AHP). Level one (target level) addresses risk identification targets (ranking and prioritizing the risk factors) which are used to make effective measures to counteract risks. Level two (criterion level) addresses different aspects of risk. In this paper, two criteria namely risk probability and risk severity is considered. Level three (risk factor level) addresses related risks of a project. The latter level usually consists of sublevels. Overall structure of levels of the proposed AHP method is depicted in Fig. 2.

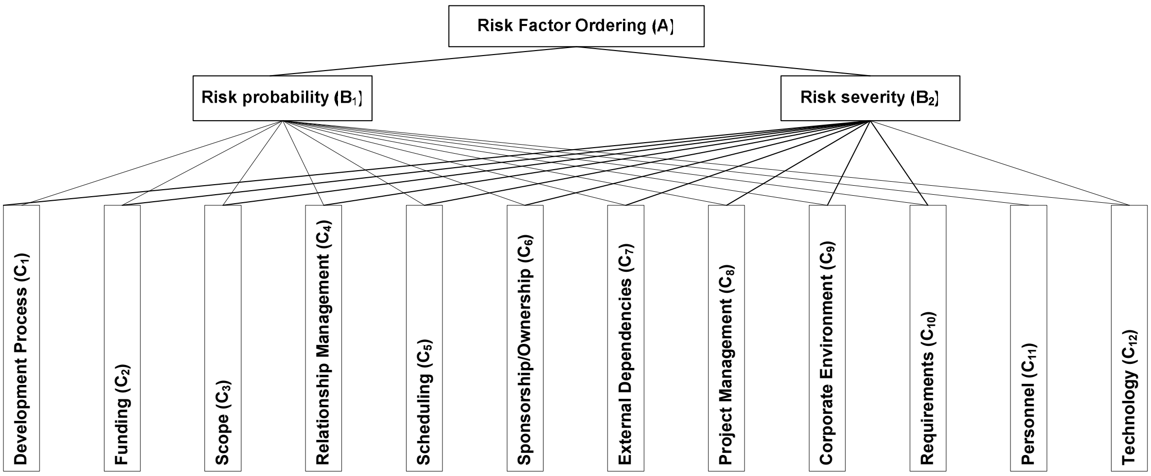

Fig. 2 Structure of project risk-factor analytic hierarchy

A. Fuzzy Analytic Hierarchy Process (FAHP)

Saaty defines analytic hierarchy process as a decision method that decomposes a complex multi-criteria decision problem into a hierarchy [15]. Analytical hierarchy process has been used extensively for solving multi-criteria decision making problems. Traditional methods of AHP can be of no use when uncertainty in data of problems is observed. To address such uncertainties, Zadeh for the first time introduced and used fuzzy sets theory [16]. Because the real world is actually full of ambiguities or in one word is fuzzy, several researches have combined fuzzy theory with AHP. A suggested methodology for fuzzy-AHP is depicted in Fig. 3.

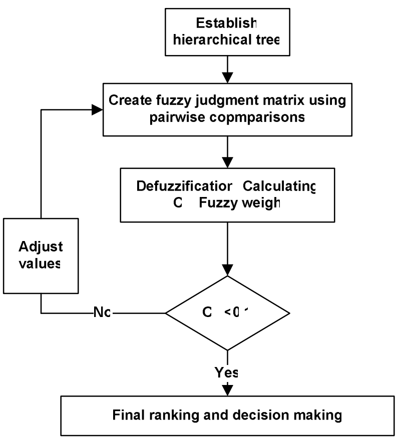

Fig. 3 A proposed methodology for fuzzy AHP

1) Establishing Hierarchical Structures

The hierarchical model should be able to break the existing complex decision problem into manageable components of different layers/levels. Different layers of the hierarchy structure of the IT projects were mentioned before and are depicted in Fig. 2.

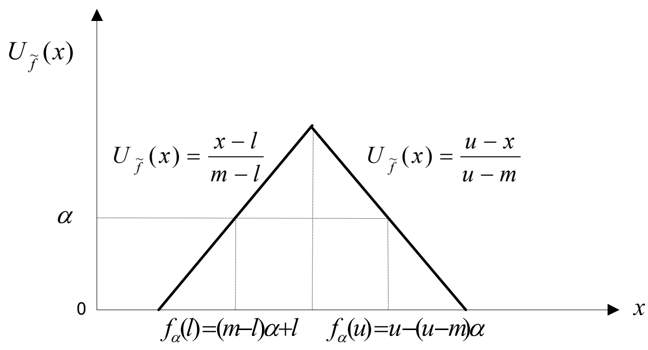

Fig 4: Left and Right representation of TFN, f_α

2) Creating Fuzzy Judgment Matrix Using Pair-Wise Comparisons

In this paper, triangular fuzzy numbers is used as the membership function, illustrated in Fig. 4. Triangular fuzzy numbers are used, because they help the decision maker to make easier decisions [17]. Membership function of a triangular fuzzy number can be found in (1) and is usually shown by the triplet *(l, m, u)*.

$$U(x)=\begin{cases}\frac{x-l}{m-l} & 1\le x\le m\\ \frac{u\text{-x}}{u\text{-}m} & m\le x\le u\\ 0 & \text{Otherwise}\end{cases} \quad (1)$$

Some of the mathematical operations of triangular fuzzy numbers are shown in Table I.

TABLE I
FUZZY ARITHMETICAL OPERATIONS USING TWO TFNS

Operators	Formulate	Results
Summation	A+B	$(l_1+l_2, m_1+m_2, u_1+u_2)$
Subtraction	A-B	$(l_1-l_2, m_1-m_2, u_1-u_2)$
Multiplication	A*B	$(l_1*l_2, m_1*m_2, u_1*u_2)$
Division	A/B	$(l_1/u_2, m_1/m_2, u_1/l_2)$

A and B are positive, and A=(l_1, m_1, u_1);B= (l_2, m_2, u_2)

The AHP method proposed by Saaty [15] uses pair-wise comparisons shown in (2). Number a_{ij} shows the relative importance of criterion i (c_i) in comparison with criterion j (c_j) in the scale of Saaty [15].

$$A=[a_{ij}]=\begin{bmatrix}1 & a_{12} & \cdots & a_{1n}\\ 1/a_{12} & 1 & \cdots & a_{2n}\\ \vdots & \vdots & \ddots & \vdots\\ 1/a_{1n} & 1/a_{2n} & \cdots & 1\end{bmatrix} \quad (2)$$

where

$a_{ij}=1:\forall i=j;\ a_{ij}=\frac{1}{a_{ji}}:\forall i\neq j$

FAHP replaces crisp a_{ij} by triangular fuzzy numbers. Because each number in the matrix shows the opinions of the experts, fuzzy number is the best solution to show expert judgments. To analyze the data and achieve the consensus of the experts, eigenvector method proposed by Buckley [18] is used here. As was said before, triangular fuzzy number (TFN) can be represented by the triplet (l, m, u). As is shown in (3-6) l, m, and n show the minimum possible, most likely and the maximum possible value of a fuzzy number, respectively. Triangular fuzzy number $\tilde{U}_{ij}$ is constructed as the following:

$$\tilde{U}_{ij}=(l_{ij},m_{ij},u_{ij}):l_{ij}\le m_{ij}\le u_{ij},l_{ij},m_{ij},u_{ij}\in[\tfrac{1}{9},9] \quad (3)$$

$$l_{ij}=\min(B_{ijk}) \quad (4)$$

$$m_{ij}=\sqrt[n]{\prod_{1}^{n}B_{ijk}} \quad (5)$$

$$u_{ij}=\max(B_{ijk}) \quad (6)$$

in which B_{ijk} stands for the relative importance of criteria c_i and c_j given by expert k.

3) Defuzzification, Calculating C.I. and Fuzzy Weights

The fuzzy matrix $\tilde{A}$ (7) will be used in the remaining steps of AHP. The number $\tilde{a}_{ij}$ is a triangular fuzzy number representing the relative importance of criteria c_i and c_j according to (3-6):

$$\tilde{A}=[\tilde{a}_{ij}]=\begin{matrix}C_1\\C_2\\\vdots\\C_n\end{matrix}\begin{bmatrix}1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n}\\ 1/\tilde{a}_{12} & 1 & \cdots & \tilde{a}_{2n}\\ \vdots & \vdots & \ddots & \vdots\\ 1/\tilde{a}_{1n} & 1/\tilde{a}_{2n} & \cdots & 1\end{bmatrix} \quad (7)$$

There are different methods to defuzzify fuzzy numbers. In this paper, the method proposed in [19] is used as shown in (8-9) to defuzzify fuzzy matrix $\tilde{A}$ into crisp matrix $G_{\alpha,\beta}$:

$$g_{\alpha,\beta}(\tilde{a}_{ij})=[\beta.f_\alpha(l_{ij})+(1-\beta).f_\alpha(u_{ij})],\ 0\le\alpha,\beta\le 1 \quad (8)$$

$$g_{\alpha,\beta}(\tilde{a}_{ij})=1/g_{\alpha,\beta}(\tilde{a}_{ji}),\ \ 0\le\alpha,\beta\le 1:i\succ j \quad (9)$$

in which $f_\alpha(l_{ij})=(m_{ij}-l_{ij}).\alpha+l_{ij}$ represents the left-end value $\alpha-cut$ for $\tilde{a}_{ij}$ and $f_\alpha(u_{ij})=u_{ij}-(u_{ij}-m_{ij}).\alpha$ represents the right-end value $\alpha-cut$ for $\tilde{a}_{ij}$.

Because this method can explicitly display preferences (α) and risk tolerance (β) of decision maker, decision makers can more thoroughly understand the risk they face in different circumstances. It is worth noting, α can be viewed as a stable or fluctuating condition. The range of uncertainty is greatest when α=1. Mean while, the decision making environment stabilizes as α increases; simultaneously, the variance in decision making decreases. Additionally, α can be any number between 0 and 1, and analysis is normally set as the following 10 numbers 0.1, 0.2,…, 1 for uncertainty emulation. Further α=0 represents the upper-bound U_{ij} and lower-bound L_{ij} for triangular fuzzy numbers, and α=1 represents the geometric mean M_{ij} in triangular fuzzy numbers. Thus, β can be viewed as the degree of pessimism in a decision maker. When $\beta=0$ the decision maker is more optimistic and the expert consensus is thus upper-bound U_{ij} of the triangular fuzzy numbers. When $\beta=1$ the decision maker is pessimistic and the number rangers from 0 to 1. However the five numbers 0.1, 0.3, 0.5, 0.7, and 0.9 are used to emulate the state of the mind of decision makers.The single pair wise comparison matrix is expressed in (10).

$$g_{\alpha,\beta}(\tilde{A})=g_{\alpha,\beta}([\tilde{a}_{ij}])=$$
$$\begin{matrix}C_1\\C_2\\\vdots\\C_n\end{matrix}\begin{bmatrix}1 & g_{\alpha,\beta}(\tilde{a}_{12}) & \cdots & g_{\alpha,\beta}(\tilde{a}_{1n})\\ 1/g_{\alpha,\beta}(\tilde{a}_{12}) & 1 & \cdots & g_{\alpha,\beta}(\tilde{a}_{2n})\\ \vdots & \vdots & \ddots & \vdots\\ 1/g_{\alpha,\beta}(\tilde{a}_{1n}) & 1/g_{\alpha,\beta}(\tilde{a}_{2n}) & \cdots & 1\end{bmatrix} \quad (10)$$

The traditional AHP uses a special case of expert judgments (geometric mean) in pair-wise comparisons which can be seen in (2-10).

Saaty [15] suggests consistency index (C.I.) and consistency rate (C.R) to verify the consistency of the matrix. Random index R.I. represents the average consistency index over numerous random entries of the same order reciprocal matrices. If $C.R.<0.1$, the estimate is accepted; otherwise, a new comparison matrix is solicited. The value of R.I depends on the value of n and should be selected from Table II.

TABLE II
RANDOM INDEX USED TO COMPUTE CONSISTENCY RATIO (C.R.)

n	1	2	3	4	…	9	10	11	12
RI	0	0	0.52	0.89	….	1.46	1.49	1.52	1.54

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To find the Consistency Index (C.I), eigen-value of the matrix $\tilde{A}$ should be found first. The number $\lambda_{\max}$ is defined as the eigen-value of the matrix $g_{\alpha,\beta}(\tilde{A})$ calculated by (11-12):

$$g_{\alpha,\beta}(\tilde{A}).W = \lambda_{\max}.W \qquad (11)$$

$$[g_{\alpha,\beta}(\tilde{A}) - \lambda_{\max}].W = 0 \qquad (12)$$

in which W is the eigenvector of matrix $g_{\alpha,\beta}(\tilde{A})$ and $0 \le \alpha, \beta \le 1$. After finding $\lambda_{\max}$, values of C.I. and C.R. can be calculated from (13-14):

$$C.I. = \frac{\lambda_{\max} - n}{n - 1} \qquad (13)$$

$$C.R. = \frac{C.I.}{R.I.} \qquad (14)$$

According to (2-6), as Table III shows, the probabilities of twelve risk factors are attained from a questionnaire filled by six different experts and then converted to fuzzy numbers based on Saaty's scale [15].

TABLE III
AGGREGATE FUZZY COMPARISON MATRIX OF PROBABILITY (LEVEL 3)

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
C_1	(1,1,1)	(0.17,0.34,1)	(0.11,0.13,2)	(0.33,0.48,0.5)	(0.33,0.43,1)	(0.33,0.86,2)	(0.14,2.34,7)	(0.17,0.48,2)	(0.14,0.47,2)	(0.2,0.32,1)	(0.33,0.38,0.5)	(0.2,2.24,9)
C_2	-	(1,1,1)	(0.11,0.19,2)	(0.33,0.47,2)	(0.33,0.39,0.5)	(0.19,0.35,0.5)	(0.11,1.91,9)	(0.17,0.78,2)	(0.12,0.24,5)	(0.25,0.43,0.5)	(0.2,0.48,1)	(0.11,2.78,9)
C_3	-	-	(1,1,1)	(0.25,0.57,2)	(0.17,0.24,5)	(0.25,0.58,3)	(1,3.25,9)	(0.11,0.35,0.5)	(0.25,0.59,3)	(0.33,0.88,3)	(1,1.68,3)	(0.11,2.36,5)
C_4	-	-	-	(1,1,1)	(0.11,0.95,3)	(0.17,0.26,2)	(0.33,2.26,5)	(0.12,0.87,3)	(0.17,0.19,1)	(0.11,0.56,3)	(0.11,0.33,3)	(0.33,1.34,8)
C_5	-	-	-	-	(1,1,1)	(0.11,0.24,2)	(0.33,0.24,5)	(0.33,0.7,1)	(0.33,0.39,0.5)	(0.11,0.48,2)	(0.12,0.47,2)	(0.14,2.87,7)
C_6	-	-	-	-	-	(1,1,1)	(0.25,1.14,8)	(0.5,0.35,5)	(0.11,0.65,3)	(0.14,0.38,1)	(0.17,0.34,5)	(0.12,2.14,5)
C_7	-	-	-	-	-		(1,1,1)	(0.33,0.78,3)	(0.2,0.39,2)	(0.17,0.67,2)	(0.2,0.35,3)	(0.25,1.98,8)
C_8	-	-	-	-	-	-	-	(1,1,1)	(0.17,0.36,1)	(0.5,0.67,3)	(0.17,0.45,3)	(0.17,2.65,9)
C_9	-	-	-	-	-	-	-	-	(1,1,1)	0.19,0.78,2)	(0.14,0.37,0.5)	(0.11,1.52,5)
C_{10}	-	-	-	-	-	-	-	-	-	(1,1,1)	(0.11,0.47,2)	(0.33,2.25,7)
C_{11}	-	-	-	-	-	-	-	-	-	-	(1,1,1)	(0.25,3.54,9)
C_{12}	-	-	-	-	-	-	-	-	-	-	-	(1,1,1)

In this paper α and β are considered equal to 0.5. Selecting $\alpha = 0.5$ indicates that environmental uncertainty is steady; additionally $\beta = 0.5$ indicates that a future attitude would be fair.

After the fuzzy matrix is made, the matrix should be defuzzified. By opting α, β equal to 0.5, C_{12} will be defuzzified according to (8-9) as an example:

$$f_{0.5}(l_{12}) = (0.34 - 0.17) \times 0.5 + 0.17 = 0.255 \qquad (15)$$

$$f_{0.5}(u_{12}) = 1 - (1 - 0.34) \times 0.5 = 0.67 \qquad (16)$$

$$g_{0.5,0.5}(a_{12}) = [0.5 \times 0.255 + (1 - .05) \times 0.67] = 2.1622 \qquad (17)$$

And finally:

$$g_{0.5,0.5}(a_{21}) = 1 / 0.4725 = 2.116 \qquad (18)$$

The final defuzzified matrix is shown in Table IV.

TABLE IV
AGGREGATE PROBABILITY COMPARISON MATRIX FOR LEVEL 3

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
C_1	1.00	0.46	0.59	0.45	0.55	1.01	2.96	0.77	0.77	0.46	0.40	3.42
C_2	2.16	1.00	0.62	0.82	0.40	0.35	3.23	0.93	1.40	0.40	0.54	3.67
C_3	1.69	1.61	1.00	0.85	1.41	1.10	4.13	0.33	1.11	1.27	1.84	2.46
C_4	2.24	1.23	1.18	1.00	1.25	0.67	2.46	1.22	0.39	1.06	0.94	2.75
C_5	1.83	2.48	0.71	0.80	1.00	0.65	1.45	0.68	0.40	0.77	0.77	3.22
C_6	0.99	2.90	0.91	1.49	1.54	1.00	2.63	1.55	1.10	0.48	1.46	2.35
C_7	0.34	0.31	0.24	0.41	0.69	0.38	1.00	1.22	0.75	0.88	0.98	3.05
C_8	1.29	1.07	3.05	0.82	1.47	0.65	0.82	1.00	0.47	1.21	1.02	3.62
C_9	1.30	0.71	0.90	2.58	2.48	0.91	1.34	2.12	1.00	0.78	0.35	2.04

C10	2.17	2.48	0.79	0.95	1.30	2.11	1.14	0.83	1.28	1.00	0.76	2.96
C11	2.52	1.85	0.54	1.06	1.31	0.68	1.03	0.98	2.90	1.31	1.00	4.08
C12	0.29	0.27	0.41	0.36	0.31	0.43	0.33	0.28	0.49	0.34	0.24	1.00

Equation (19) is used to determine eigen-value $\lambda_{\max}$:

$$\det(A-\lambda I)=0$$
$$\Rightarrow \begin{Vmatrix} 1\text{-}\lambda & 0.46 & 0.59 & 0.45 & 0.55 & 1.01 & 2.96 & 0.77 & 0.77 & 0.46 & 0.40 & 3.42 \\ 2.16 & 1\text{-}\lambda & 0.62 & 0.82 & 0.40 & 0.35 & 3.23 & 0.93 & 1.40 & 0.40 & 0.54 & 3.67 \\ 1.69 & 1.61 & 1\text{-}\lambda & 0.85 & 1.41 & 1.10 & 4.13 & 0.33 & 1.11 & 1.27 & 1.84 & 2.46 \\ 2.24 & 1.23 & 1.18 & 1\text{-}\lambda & 1.25 & 0.67 & 2.46 & 1.22 & 0.39 & 1.06 & 0.94 & 2.75 \\ 1.83 & 2.48 & 0.71 & 0.80 & 1\text{-}\lambda & 0.65 & 1.45 & 0.68 & 0.40 & 0.77 & 0.77 & 3.22 \\ 0.99 & 2.90 & 0.91 & 1.49 & 1.54 & 1\text{-}\lambda & 2.63 & 1.55 & 1.10 & 0.48 & 1.46 & 2.35 \\ 0.34 & 0.31 & 0.24 & 0.41 & 0.69 & 0.38 & 1\text{-}\lambda & 1.22 & 0.75 & 0.88 & 0.98 & 3.05 \\ 1.29 & 1.07 & 3.05 & 0.82 & 1.47 & 0.65 & 0.82 & 1\text{-}\lambda & 0.47 & 1.21 & 1.02 & 3.62 \\ 1.30 & 0.71 & 0.90 & 2.58 & 2.48 & 0.91 & 1.34 & 2.12 & 1\text{-}\lambda & 0.78 & 0.35 & 2.04 \\ 2.17 & 2.48 & 0.79 & 0.95 & 1.30 & 2.11 & 1.14 & 0.83 & 1.28 & 1\text{-}\lambda & 0.76 & 2.96 \\ 2.52 & 1.85 & 0.54 & 1.06 & 1.31 & 0.68 & 1.03 & 0.98 & 2.90 & 1.31 & 1\text{-}\lambda & 4.08 \\ 0.29 & 0.27 & 0.41 & 0.36 & 0.31 & 0.43 & 0.33 & 0.28 & 0.49 & 0.34 & 0.24 & 1\text{-}\lambda \end{Vmatrix} = 0 \quad (19)$$

After solving (19) $\lambda_{\max}$ will be 13.2672. So by using (12) W will be:

$$(A-\lambda I)\times W = 0$$
$$\Rightarrow \begin{bmatrix} 12.27 & 0.46 & 0.59 & 0.45 & 0.55 & 1.01 & 2.96 & 0.77 & 0.77 & 0.46 & 0.40 & 3.42 \\ 2.16 & 12.27 & 0.62 & 0.82 & 0.40 & 0.35 & 3.23 & 0.93 & 1.40 & 0.40 & 0.54 & 3.67 \\ 1.69 & 1.61 & 12.27 & 0.85 & 1.41 & 1.10 & 4.13 & 0.33 & 1.11 & 1.27 & 1.84 & 2.46 \\ 2.24 & 1.23 & 1.18 & 12.27 & 1.25 & 0.67 & 2.46 & 1.22 & 0.39 & 1.06 & 0.94 & 2.75 \\ 1.83 & 2.48 & 0.71 & 0.80 & 12.27 & 0.65 & 1.45 & 0.68 & 0.40 & 0.77 & 0.77 & 3.22 \\ 0.99 & 2.90 & 0.91 & 1.49 & 1.54 & 12.27 & 2.63 & 1.55 & 1.10 & 0.48 & 1.46 & 2.35 \\ 0.34 & 0.31 & 0.24 & 0.41 & 0.69 & 0.38 & 12.27 & 1.22 & 0.75 & 0.88 & 0.98 & 3.05 \\ 1.29 & 1.07 & 3.05 & 0.82 & 1.47 & 0.65 & 0.82 & 12.27 & 0.47 & 1.21 & 1.02 & 3.62 \\ 1.30 & 0.71 & 0.90 & 2.58 & 2.48 & 0.91 & 1.34 & 2.12 & 12.27 & 0.78 & 0.35 & 2.04 \\ 2.17 & 2.48 & 0.79 & 0.95 & 1.30 & 2.11 & 1.14 & 0.83 & 1.28 & 12.27 & 0.76 & 2.96 \\ 2.52 & 1.85 & 0.54 & 1.06 & 1.31 & 0.68 & 1.03 & 0.98 & 2.90 & 1.31 & 12.27 & 4.08 \\ 0.29 & 0.27 & 0.41 & 0.36 & 0.31 & 0.43 & 0.33 & 0.28 & 0.49 & 0.34 & 0.24 & 12.27 \end{bmatrix} \times \begin{bmatrix} W_{P1} \\ W_{P2} \\ W_{P3} \\ W_{P4} \\ W_{P5} \\ W_{P6} \\ W_{P7} \\ W_{P8} \\ W_{P9} \\ W_{P10} \\ W_{P11} \\ W_{P12} \end{bmatrix} = 0 \quad (20)$$

After solving (20), the W will be:

$$W_p = [0.0634 \quad 0.0768 \quad 0.1050 \quad 0.0895 \quad 0.0775 \quad 0.1059 \quad 0.0543 \quad 0.0947 \quad 0.0976 \quad 0.1016 \quad 0.1063 \quad 0.0274]^t \quad (21)$$

Then C.I. is calculated as the following:

$$C.I. = \frac{\lambda_{\max} - n}{n-1} = \frac{13.262-12}{12-1} = 0.1152,$$
$$C.R. = \frac{C.I.}{R.I.} = \frac{0.1152}{1.54} = 0.0748 < 0.1 \quad (22)$$

The C.R. shows that the risk probability is consistent. The same calculations can be done for risk severity in level 3 and for level 2 for risk probability and risk severity. The results are shown in Table V.

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TABLE V
FINAL PRIORITY WEIGHTS FOR LEVELS OF AHP

Level	Priority Weight
level 2	(0.75, 0.25)
level 3 for probability	(0.0634,0.0768,0.105,0.0895,0.0775,0.1059,0.0543,0.0947,0.0976,0.1016,0.1063,0.0274)
level 3 for severity	(0.0915,0.0585,0.0908,0.1116,0.0616,0.0845,0.0714,0.1075,0.0835,0.0865,0.084,0.0686)
Total	(0.070425,0.072225,0.10145,0.095025,0.073525,0.10055,0.058575,0.0979,0.094075,0.097825,0.100725,0.0377)

1) Final Ranking

Based on the attained results shown in Table V, the final ranking will be:

$C_3 > C_{11} > C_6 > C_8 > C_{10} > C_4 > C_9 > C_5 > C_2 > C_1 > C_7 > C_{12}$

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REFERENCES

[1] R. Gardner, CEO to IT: Teach us, computer world, October 19, 1998.
[2] Chapman, C.B. and Cooper, D.F. (1983), "Risk analysis: testing some prejudices", European Journal of Operational Research, Vol.14, pp.238-47.
[3] PMI. A guide to the project management body of knowledge: PMBOK Guide. 3rd ed. USA: Project Management Institute Inc; 2004.
[4] B.W. Boehm, Software risk management: principles and practices, IEEE Software 8 (1) (1991).
[5] A. Lederer, J. Prasad, Information systems software cost estimate: a current assessment, Journal of Information Technology 8(1), 1993.
[6] M. Mehler, Reining in runaway systems, Information Week (1991) 20-24.
[7] Standish Group International. 2002. Latest Standish Group CHAOS report shows project success rate has improved by 50%. Press release, 25 March 2002. [online] URL: http://www.standishgroup.com/press/article.php?id=2. Accessed 8 April 2004.
[8] H. Barki, S. Rivard, J. Talbot. Toward an assessment of software development risk, Journal of Management Information Systems 10 (2) (1993).
[9] L. Wallace, M. Keil, A. Rai, How software project risk affects project performance: an investigation of the dimensions of risk and an exploratory model, Decision Sciences 35 (2) (2004).
[10] Tüysüz F., Kahraman C., Project risk evaluation using a fuzzy analytic hierarchy process: an application to information technology projects, international journal of intelligent systems (12), 2006. 559-84.
[11] R. Schmidt, K. Lyytinen, M. Keil, P. Cule, Identifying software project risks: an International Delphi Study, Journal of Management Information Systems 17 (4) (2001).
[12] McFarlan, F.W. 1981. Portfolio approach to information systems, Harvard Business Review, September-October: 142-150.
[13] Klein, R., Risk management for business process reengineering projects. Information Systems Management 17(4), 2001. 71-73.
[14] Addison, T., E-commerce project development risks: evidence from a Delphi survey, International Journal of Information Management 23(1), 2003. 25-40.
[15] Saaty, T.L. (1980). The analytic hierarchy process. New York: McGraw Hill.
[16] Zadeh, L. (1965). Fuzzy sets. Information Control, 8, 338-353.
[17] Kaufmann, A. and Gupta, M. M. (1988). Fuzzy mathematical models in engineering and management science. Netherlands: Elsevier Science Publisher.
[18] Buckley, J.J. (1985). Fuzzy hierarchal Fuzzy Sets and Systems, 17, 233-247.
[19] Liou, T.S. and Wang, M.J.J. (1992). Ranking fuzzy numbers with integral value. Fuzzy Sets and Systems, 50(3), 247-255.