A Fuzzy MCDM for Evaluating Risk of Construction Projects

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Abstract: Construction projects deal with various threats which are called risks. If we do not have good strategies to identify and perform preventive actions for these threats, the project may fail. In the risk management process, contractors are faced by some unintelligible problems such as cultural problems, fundamental problems and changing of policies. If we want to succeed in project we should identify, analyze, manage and control the risks. These tasks must be implemented by contractors. A project must complete in predetermined time and quality according to limited budget. Therefore the risk management of project is very important to succeed in project. One of the most important steps in risk management process is identifying risk factors of a project. In this study, the important risk factors are categorized into two main groups as internal factors and external factors. Each main group consists of several factors. A prevalent problem that is investigated by researchers in project risk management is specifying risks of threats to which the project is exposed. For evaluating the risk of threats, we rank them in terms of their probability and severity. In this study risk evaluation of construction project is investigated by the proposed fuzzy analytical hierarchy process (FAHP). The risk factors are prioritized by using analytical hierarchy process. For illustrating the FAHP method, a case study is presented.

Key words:

INTRODUCTION

The construction industry, probably more than any other industries, is facing with various risks that lead in poor performance, increase of expenses, and tardiness of the delivery and even failure of the project (An et al., 2005). Risks show the conditions that are out of control of the project team and if they are not truly managed, they will cause adverse influence on the project. Project managers attempt to solve the potential problems before they take place and this is done by applying risk management techniques. Risk was defined by Chapman and Cooper (Chapman and Cooper, 1983) 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”. A methodology for indentifying, measuring, evaluation, controlling and monitoring the risk was developed by Tummala and Leung (Tummala et al., 1999). They used the proposed methodology to manage the cost risk of an EHV transmission line project. Project management, considers the risk management as one of its core knowledge areas (PMI, 2004; Wang and Chou. 2003). Project risk was defined in PMBOK as “An uncertain event or condition that, if it occurs, has a positive or a negative effect on at least one project objective, such as time, cost, scope, or quality, which implies an uncertainly about identified events and conditions” (PMI, 2004). Risk management is defined as follows: Risk Management is the identification, assessment, and prioritization of risks followed by coordinated and economical application of resources to minimize, monitor, and control the probability and/or impact of unfortunate events. Risk management is consisting of two major stages. These two stages are risk assessment and risk control. The risk assessment is composed of risk identification, risk analysis and risks prioritization step. The risk control consist of risk mitigation, planning for emergencies and measuring and control step. As stated, the risk identification is the first step of risk management. The definition of each steps are as follows:
1. Identification: denote the threats of project.
2. Analysis: recognize the manner of these threats on project.
3. Prioritization: ranking these threats according to its impact.

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4. Mitigation: identify the possible preventive actions which reduce the effect of risk.
5. Planning: construct an in place plan for significant risks to perform before risk happens.
6. Measuring and control: manage, control and trace the impact of risks to succeed in goals of project.

Figure 1 shows the risk management stages and its steps.

![Risk Management Stages](image)

Fig. 1: risk management stages and its steps

Risk can be measured by different approaches. In this study, for evaluating the risk of construction factors, first we identify the risks of construction project that may occur during project; and then we prioritize risk factors of construction project by the proposed fuzzy MCDM, that is used for evaluating the risk of factor. For identifying the risk factors of construction projects the literature of risk management of construction project should be surveyed. Assaf and Hejji (2006) listed 73 causes of delay in large construction projects. They categorized them into nine groups such as project, owner, contractor, design, materials, equipment, labors and external. In another paper by Ismail et al. (2008), ten risk factors was identified and classified into two groups as internal risk factors and external risk factors. Zayed et al. (2008) identified the risk sources of highway projects. They recognize 7 main groups of risk and construct a hierarchy structure of risk factors in 3 levels. Iyer and Jha (2005) investigated the risk factors into two classes as critical success attributes and critical failure attributes. They identified 30 critical success factors and 23 critical failure factors. One of the complete surveys in construction project risk factors was performed by Saqib et al. (2008). They identified 77 risk factors and categorized them in 7 main groups as Project Management Factors, Procurement-related Factors, Client-related Factors, Design team-related Factors, Contractor-related factors, Project Manager-related Factors and Business and Work Environment-related Factors. These 7 categories cover every influence threat that has impact on critical elements of construction projects. According to the environment and fundamental conditions of construction projects in Iran, we use the factor classification by Saqib et al. (2008) plus two new classes of risk factors as market competition risks and quality risks. Each main group of risk factors contains sub-factors. Figure 2 shows the identified risk factors of construction projects in Iran.

There exists different approaches and methodologies to simplify risk evaluation. The expert judgment, plan analysis, decision drives, and brain storming were used by Turner (1999) to recognize the events that might be a risk in project. The Delphi approach was suggested by Day (1999) to recognize the risk factors. Perry and Hayes (1985) constructed a checklist of the risks that may happen during lifespan of a project. Baloi and Price (2003) discuss that almost all the risk analysis tools based on the theory of statistical decision making are seldom employed by the contractors practically and so suggest that knowledge, experience, intuitive opinions of experts, and general rules should be used to evaluate risks. They used fuzzy sets theory to appraise risk and suggested a fuzzy decision support tool to estimate cost risk. General risk factors such as political and economical ones have been studied in several researches. For example, Ashley and Boner (1987) analyzed political risk factor in projects and developed a method using influence diagrams to identify main sources of political risk factor and their influence on success of a project. Kapila and Hendrickson (2001) indicated financial risk factors in international construction projects. The proposed method implemented to evaluate the risk of factors in this study is based on a multi-criteria decision making (MCDM) tool and analytical hierarchy process (AHP). The reason of using both MCDM and AHP is that risk estimation of factors in construction project is based on viewpoint and experience of experts. Figure 3 shows the proposed hierarchical tree to prioritize and evaluate of risk factors.

The main aims of this study are to identify the risk factors of construction projects in Iran's environment and generally in developing countries, and also to recognize the importance grade of each factor. For achieving these goals, available research papers in construction project risk management are reviewed. The 38 identified risk factors are categorized in 9 main groups and a hierarchy structure of risk factors is provided. For using fuzzy analytical hierarchy process technique we need experts’ judgments. Therefore for collecting the opinion
of judgments, a questionnaire which contains all main factors and sub-factors are distributed among project managers of the organization. Then by using FAHP technique importance grade of main-factors and sub-factors are calculated and then the factors are prioritized.

**Fig. 2:** the identified risk factors and sub factors related to construction projects

**Fuzzy Analytical Hierarchy Process (FAHP):**
Multi-criteria decision-making methods are effective tools that assist in confronting decision challenging. Analytic hierarchy process (AHP) is as one of the popular methods used in multi criteria decision-making processes. Saaty (1980; 1986) defines analytic hierarchy process as a decision method that decomposes a complex multi-criteria decision problem into a hierarchy. One of the main benefits of AHP is its relative easiness with which it handles multiple criteria. AHP allows decision makers to model a complex problem in a hierarchical structure which consists of the goal, objectives (criteria), sub-objectives, and alternatives (1990). Traditional methods of AHP cannot be used when uncertainty in data of problems is observed (Hahn, 2003).

To address such uncertainties, Zadeh (1965) for the first time introduced the fuzzy set theory, which was based on the rationality of uncertainty due to imprecision or vagueness. A major contribution of fuzzy set theory is its capability of representing uncertainty knowledge. Because our around world is actually full of ambiguities or in one word is fuzzy, several researchers have combined fuzzy theory with AHP. Van Laarhoven and Pedrycz (1983) proposed the first method of implementing Fuzzy AHP in 1983 in which triangular fuzzy numbers were compared according to their membership functions. FAHP method was used in various research areas for decision making in different fields such as selecting, prioritizing, evaluating, and so on. Readers can refer to (Iranmanesh et al., 2008) for the further studies. Required steps for applying FAHP in evaluating construction risk factors are as follows. Figure 4 illustrates the needed steps to be taken in this paper.

**Step 1: Establishing hierarchical structures:**
The first step in fuzzy analytic hierarchy process is establishing a hierarchal tree based on our goal which here is evaluating the construction project factors. Different layers of the hierarchy structure of key factors influencing on successful implementation of knowledge management were mentioned before depicted in Figure 4.

**Step 2: Creating Fuzzy Judgment Matrix Using Pair-wise Comparisons:**
According to Kaufmann and Gupta (1988), triangular fuzzy numbers (TFNs) help the decision maker to make easier decisions. Hence, in this paper TFN is used as the membership function. Membership function of a TFN is as equation (1) and is shown by the triplet \((l, m, u)\).
Fig. 3: the proposed hierarchical tree

Fig. 4: the required steps for FAHP
Saaty (1980) proposed pair-wise comparisons to create the fuzzy judgment matrix. Equation (2) illustrate the pair-wise comparisons or fuzzy judgment matrix which used in AHP technique. Number $a_{ij}$ indicates the relative importance of criterion $i$ ($c_i$) in comparison with criterion $j$ ($c_j$) in the scale of Saaty (1980).

$$A = \begin{bmatrix} c_1 & c_2 & \cdots & c_n \\ c_1^{-1} & 1 & \cdots & a_{i1} \\ \vdots & \vdots & \ddots & \vdots \\ c_n^{-1} & 1/a_{ni} & \cdots & 1 \end{bmatrix}$$

Where

$$a_{ij} = 1 : \forall i = j; \quad a_{ij} = 1/a_{ij} : \forall i \neq j$$

FAHP substitutes crisp number $a_{ij}$ by triangular fuzzy numbers. Because each number in the matrix $A$ shows the experts’ judgment, fuzzy numbers are the best solution for translating expert opinions. The Eigenvector method which is proposed by Buckley (1985) is used in this paper to analyze and achieve the consensus of the experts. As above mentioned, TFN can be shown by the triplet $(l, m, u)$. The equations (4-6) show the minimum possible, most likely and the maximum possible value of a fuzzy number $(l, m, u)$.

Triangular fuzzy number ($\tilde{U}_{ij}$) is established as the following according to Saaty Scale:

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

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

$$m_{ij} = \sqrt{n} \prod_{k} B_{ijk}$$

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

In which $B_{ijk}$ show the relative importance of criteria $c_i$ and $c_j$ given by expert $k$.

**Step 3: Defuzzification, Calculating C.R. and fuzzy weights:**

Matrix $\tilde{A}$ (7) is defined for the rest of AHP method. The number $\tilde{a}_{ij}$ in Matrix $\tilde{A}$ is a triangular fuzzy number and shows the relative importance of criteria $c_i$ and $c_j$ according to equations (3-6):

$$\tilde{A} = [\tilde{a}_{ij}] = \begin{bmatrix} C_1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ 1 & C_2 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ C_n & 1/\tilde{a}_{n1} & \cdots & 1 \end{bmatrix}$$
In this step, we need defuzzification process. In this paper, the method proposed by Liou and Wang in (1992) is used:

The Liou and Wang’s method (1992) to defuzzify fuzzy matrix $\tilde{A}$ into crisp matrix $h_{\alpha,\beta}$ is shown in (8-9):

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

$$h_{\alpha,\beta}(\tilde{a}_{ij}) = 1/h_{\alpha,\beta}(\tilde{a}_{ji}), \quad 0 \leq \alpha, \beta \leq 1 : i > j \quad (9)$$

In which $(\alpha)$, $(\beta)$ are preference and risk tolerance of the decision maker, respectively.

The single pair wise comparison matrix is stated in (10).

$$h_{\alpha,\beta}(\tilde{A}) = h_{\alpha,\beta}([\tilde{a}_{ij}]) = \begin{bmatrix}
C_1 & C_2 & \ldots & C_n \\
1 & h_{\alpha,\beta}(\tilde{a}_{12}) & \ldots & h_{\alpha,\beta}(\tilde{a}_{1n}) \\
1/h_{\alpha,\beta}(\tilde{a}_{21}) & 1 & \ldots & h_{\alpha,\beta}(\tilde{a}_{2n}) \\
\vdots & \vdots & \ddots & \vdots \\
1/h_{\alpha,\beta}(\tilde{a}_{n1}) & 1/h_{\alpha,\beta}(\tilde{a}_{n2}) & \ldots & 1
\end{bmatrix} \quad (10)$$

**Step 4: Checking consistency:**

To validate the consistency of the matrix, Saaty (1980) proposes consistency index (C.I.) and consistency ratio (C.R.). Random index (R.I.) shows the average consistency index over numerous random entries of the same order reciprocal matrices. The value of R.I depends on the Saaty’s Scale (1980). If $C.R < 0.1$, the approximation is accepted; otherwise, a new comparison matrix is solicited.

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

$$h_{\alpha,\beta}(\tilde{A})W - \lambda_{\text{max}} W = 0 \quad (11)$$

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

In which $W$ is the eigenvector of matrix $h_{\alpha,\beta}(\tilde{A})$ and also $W$ indicates the weights of criteria $C_i$ to $C_n$.

After calculating $\lambda_{\text{max}}$, values of C.I. and C.R. can be calculated according to equations (13-14):

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

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

**Step 5: Final Ranking and Decision Makings:**

After calculating the local weights for all levels of the hierarchical tree to evaluate construction risk factors, we can find the final weight of the alternatives or final level of hierarchical tree and then the decision makers can make decision based on the weight of alternatives.

**Evaluating the Risk Factors of Construction Projects by Fuzzy AHP:**

In risk evaluation process of construction project, we are exposed to uncertainty. Project managers express the risk as linguistic term such as low, medium or high also, we deal with lack of exact data. So using fuzzy set theory for expressing the risk is more useful. By using fuzzy set theory representation of project manager’s idea is simpler than other methods. In using AHP method without integrating it with fuzzy set theory, we don’t really consider the project manager’s idea. Iranmanesh et al. (2008) used FAHP technique for evaluating the risk factors of information technology projects. In accordance with the advantages of FAHP technique stated above, FAHP has been applied to evaluate the risk factors of construction projects.
For implementing the FAHP, we need pair-wise comparisons of risk factors. To collect the project managers’ idea about the risk factors, a questionnaire was provided and distributed among 15 project managers of some Iran’s organization which works in construction project area.

Now, we implement the proposed methodology on an actual case in construction area. Based on equations (2-6), and Table 1, the fuzzy decision matrices for second level’s criteria of hierarchal tree in Figure 3 are achieved from a verbal questionnaire filled by 15 different experts and then converted to fuzzy numbers based on Saaty’s scale (1980; 1986). In this study, α and β are set equal to 0.5. As above mentioned, α=0.5 Shows that environmental uncertainty is steady; and β=0.5 shows that a prospect attitude would be fair.

Table 1: fuzzy pair-wise comparison of level 2 of hierarchal tree for risk evaluation

<table>
<thead>
<tr>
<th></th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
<th>C7</th>
<th>C8</th>
<th>C9</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>(1,1)</td>
<td>(0.12,0.64,3)</td>
<td>(0.17,0.36,1)</td>
<td>(0.12,0.325,3)</td>
<td>(0.2,0.43,1)</td>
<td>(0.25,0.75,3)</td>
<td>(0.12,2.53,6)</td>
<td>(0.12,0.64,3)</td>
<td>(0.14,0.47,2)</td>
</tr>
<tr>
<td>C2</td>
<td>(1,1)</td>
<td>(0.11,0.19,2)</td>
<td>(0.12,0.45,2)</td>
<td>(0.25,0.39,2)</td>
<td>(0.16,0.46,2)</td>
<td>(0.17,1.86,8)</td>
<td>(0.2,0.68,4)</td>
<td>(0.12,0.24,5)</td>
<td></td>
</tr>
<tr>
<td>C3</td>
<td>(1,1)</td>
<td>(0.25,0.57,2)</td>
<td>(0.17,0.24,4)</td>
<td>(0.25,0.62,4)</td>
<td>(1.2,2.57,7)</td>
<td>(0.12,0.19,1)</td>
<td>(0.25,0.59,3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C4</td>
<td>(1,1)</td>
<td>(0.12,1.95,5)</td>
<td>(0.11,0.32,2)</td>
<td>(0.23,2.45)</td>
<td>(0.11,0.56,2)</td>
<td>(0.17,0.19,1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C5</td>
<td>(1,1)</td>
<td>(1.1,1)</td>
<td>(0.12,0.26,2)</td>
<td>(0.21,2.45)</td>
<td>(0.25,0.37,1)</td>
<td>(0.33,0.39,0.5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C6</td>
<td>(1,1)</td>
<td>(1,1,1)</td>
<td>(0.25,1.14,9)</td>
<td>(0.5,1.15,6)</td>
<td>(0.11,0.56,3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C7</td>
<td>(1,1,1)</td>
<td>(0.25,0.48,2)</td>
<td>(0.2,0.39,2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C8</td>
<td>(1,1,1)</td>
<td>(0.17,0.36,1)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>C9</td>
<td>(1,1,1)</td>
<td>(1,1,1)</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Based on step 1, after building the fuzzy matrix, we now need to defuzzify the matrix that was built in previous step. The final defuzzified matrix is shown in Table 2. Above Matrix can be defuzzified based on equations (8-9) as an example:

\[ f_{0.5}(u_{12}) = (0.64 - 0.12) \times 0.5 + 0.12 = 0.38 \]

\[ f_{0.5}(u_{12}) = 3 - (3 - 0.64) \times 0.5 = 1.82 \]

\[ h_{0.5,0.5}(a_{12}) = [0.5 \times 0.38 + (1 - 0.5) \times 1.82] = 1.1 \]

And finally:

\[ h_{0.5,0.5}(a_{21}) = 1/1.1 = 0.9091 \]

Table 2: Aggregate comparison matrix for level 2 of hierarchal tree for risk evaluation

<table>
<thead>
<tr>
<th></th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
<th>C7</th>
<th>C8</th>
<th>C9</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>1</td>
<td>0.4725</td>
<td>0.9425</td>
<td>0.5150</td>
<td>1.1875</td>
<td>2.7950</td>
<td>1.1000</td>
<td>0.7700</td>
<td></td>
</tr>
<tr>
<td>C2</td>
<td>0.9091</td>
<td>1</td>
<td>0.6225</td>
<td>0.7550</td>
<td>0.7575</td>
<td>0.7000</td>
<td>2.9725</td>
<td>1.3900</td>
<td>1.4000</td>
</tr>
<tr>
<td>C3</td>
<td>2.1164</td>
<td>1.6064</td>
<td>1</td>
<td>0.8475</td>
<td>1.1625</td>
<td>1.3725</td>
<td>3.1250</td>
<td>0.3750</td>
<td>1.1075</td>
</tr>
<tr>
<td>C4</td>
<td>1.0610</td>
<td>1.3245</td>
<td>1.1799</td>
<td>2.2550</td>
<td>0.6875</td>
<td>2.9200</td>
<td>0.8075</td>
<td>0.3875</td>
<td></td>
</tr>
<tr>
<td>C5</td>
<td>1.9417</td>
<td>1.3201</td>
<td>0.8602</td>
<td>0.4435</td>
<td>1</td>
<td>0.6600</td>
<td>1.9200</td>
<td>0.4975</td>
<td>0.4025</td>
</tr>
<tr>
<td>C6</td>
<td>0.8421</td>
<td>1.2987</td>
<td>0.7286</td>
<td>1.4545</td>
<td>1.5152</td>
<td>1</td>
<td>2.8825</td>
<td>2.200</td>
<td>1.1025</td>
</tr>
<tr>
<td>C7</td>
<td>0.3578</td>
<td>0.3364</td>
<td>0.3200</td>
<td>0.3425</td>
<td>0.5208</td>
<td>0.3469</td>
<td>1</td>
<td>0.8025</td>
<td>0.7450</td>
</tr>
<tr>
<td>C8</td>
<td>0.9091</td>
<td>0.7194</td>
<td>2.6667</td>
<td>1.2384</td>
<td>2.0101</td>
<td>0.4545</td>
<td>1.2461</td>
<td>1</td>
<td>0.4725</td>
</tr>
<tr>
<td>C9</td>
<td>1.2987</td>
<td>0.7143</td>
<td>0.9029</td>
<td>2.5806</td>
<td>2.4845</td>
<td>0.9070</td>
<td>1.3423</td>
<td>2.1164</td>
<td>1</td>
</tr>
</tbody>
</table>

After solving equations (11-12) for above matrix, weights and eigen-value of the matrix (\( \lambda_{\text{max}} \)) of main risk factors in level 2 can be calculated. The weighs and eigen-value of the matrix are as follows.

\[ W = [0.1007, 0.1089, 0.1305, 0.1147, 0.092, 0.1363, 0.0525, 0.1183, 0.1471] \]

As a result of above calculations, the weights of nine criteria of level 2 i.e. Project Management, Procurement, Client, Design team, Contractor, Project Manager, Business and Work Environment-related, market competition, and Quality are 0.1007, 0.1089, 0.1305, 0.1147, 0.092, 0.1363, 0.0525, 0.1183, and 0.1471. Eigen-value is 9.7966.

And Therefore, Consistency Index (C.I.) is calculated as the following:

\[ C.I. = \frac{\lambda_{\text{max}} - n}{n - 1} = \frac{9.7966 - 9}{9 - 1} = 0.0996 \]

\[ C.R. = \frac{C.I.}{R.I.} = \frac{0.0996}{1.45} = 0.0687 \leq 0.1 \]
The results show that the above mentioned decision matrix for the second level of the hierarchical tree for risk evaluation of construction project is consistent. After calculating the local weights of whole criteria of the level 2 and sub-criteria related to them, it is time for calculating final weights of sub-criteria in hierarchical tree. For calculating the final weight of sub-criteria, which shows the importance rate of sub-criteria based on experts’ judgments, it is essential to multiply weights of sub-criteria of the third level by weights of the first level criteria in the proposed hierarchical tree. Table 3 shows the weights of the level 2 of hierarchical tree, the weights of the sub-criteria level and final weights of criteria.

After doing all of calculations, we can sort factors from up to down based on weights and also prioritize risk factors of the construction project in Iran from the most important to the least important risk factors based on experts’ judgments. Table 4 shows the results of this priority.

<table>
<thead>
<tr>
<th>Table 3: weights related to factors and sub-factors</th>
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<tbody>
<tr>
<td>Main factors of level 2 in hierarchal structure</td>
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<td>C1</td>
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<tr>
<td>C7</td>
</tr>
<tr>
<td>C72</td>
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<tr>
<td>C73</td>
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<td>C74</td>
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<tr>
<td>C75</td>
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<tr>
<td>C8</td>
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<tr>
<td>C82</td>
</tr>
<tr>
<td>C83</td>
</tr>
<tr>
<td>C9</td>
</tr>
<tr>
<td>C92</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 4: prioritizing the risk factors based on their weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Risk factor</td>
</tr>
<tr>
<td>Bad quality of materials</td>
</tr>
<tr>
<td>Bad quality of workmanship</td>
</tr>
<tr>
<td>Fierce competition</td>
</tr>
<tr>
<td>Project contract mechanism (e.g. lump sum, unit price, cost)</td>
</tr>
<tr>
<td>Project Manager’s experience and decision capability</td>
</tr>
<tr>
<td>Project design complexity</td>
</tr>
<tr>
<td>Adequacy of plans and specifications</td>
</tr>
<tr>
<td>Lack of follow-up project</td>
</tr>
<tr>
<td>Client’s confidence in construction team</td>
</tr>
<tr>
<td>Communication and system control</td>
</tr>
</tbody>
</table>
These results demonstrate the quality is more important than other main factors and the business and work environment has minimum importance grade among the main risk factors. Table 5 shows the most important sub-factor of each main factor.

### Table 5: the most important sub-factor related to each main factor

<table>
<thead>
<tr>
<th>Main Factor</th>
<th>Weight</th>
<th>Most Important Sub-Factor</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality</td>
<td>0.1471</td>
<td>Bad quality of materials</td>
<td>0.085818</td>
</tr>
<tr>
<td>Project Manager</td>
<td>0.1363</td>
<td>Project Manager’s experience and decision capability</td>
<td>0.043125</td>
</tr>
<tr>
<td>Client</td>
<td>0.1305</td>
<td>Client’s confidence in construction team</td>
<td>0.031555</td>
</tr>
<tr>
<td>Market Competition</td>
<td>0.1183</td>
<td>Project design complexity</td>
<td>0.040673</td>
</tr>
<tr>
<td>Team Design</td>
<td>0.1147</td>
<td>Speed of information flow</td>
<td>0.030700</td>
</tr>
<tr>
<td>Procurement</td>
<td>0.1089</td>
<td>Project Manager’s experience and decision capability</td>
<td>0.043125</td>
</tr>
<tr>
<td>Project Management</td>
<td>0.1007</td>
<td>Industrial relations environment</td>
<td>0.012854</td>
</tr>
<tr>
<td>Contractor</td>
<td>0.0930</td>
<td>Fierce competition</td>
<td>0.056855</td>
</tr>
<tr>
<td>Business and Work Environment</td>
<td>0.0515</td>
<td>Bad quality of materials</td>
<td>0.085818</td>
</tr>
</tbody>
</table>

### Conclusion:

The ranking of risk factors help project managers to make a good decision about risk factors and perform appropriate preventive actions against the harmful effect of risk on outcome of project. Fuzzy risk assessment is a powerful tool for quantifying the estimated risk when importance of risk is expresses in terms of linguistic variables. In this paper an approach based on fuzzy logic and analytical hierarchy process is suggested for ranking the risk factors of construction projects. Applicability of Fuzzy AHP methodology has been tested on a real case. In this study the risk factors of construction projects in Iran has been identified and classified, then by using FAHP approach they are prioritized. By reviewing the available papers of construction project in literature and localizing them, 38 risk factors has been identified and classified in 9 main classes. By implementing the FAHP method the importance grade of risk factors has been recognized. Evidences show that the quality factor is more important than other main factors and business and work environment main factor have minimum importance grade among all main factors. The bad quality of materials is given maximum importance grade among all sub-factors and Contractor’s cash flow is given minimum importance grade. For further and future research comparison of this study with other methods can be implemented. Implementing this approach on other applicable areas is also suggested.
REFERENCES


