Sigma J Eng & Nat Sci 38 (3), 2020, 1447-1462

Sigma Journal of Engineering and Natural Sciences
Sigma Mühendislik ve Fen Bilimleri Dergisi

Research Article

ASSESSMENT OF PROJECT CHARACTERISTICS AFFECTING RISK OCCURRENCES IN CONSTRUCTION PROJECTS USING FUZZY AHP

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Received: 24.02.2020 Revised: 25.05.2020 Accepted: 25.07.2020

ABSTRACT

The performance of the construction industry has been widely criticized in the literature due to substantial delays and cost overruns. The dynamic, turbulent, and complex environment of the construction industry can lead to poor performance causing occurrence of numerous risks that can adversely affect the performance of the projects. Risk management plays an important role in the improvement of performance of construction projects. However, performance of risk management is challenging due to limited availability of information, particularly during the risk identification stage. This study aims to identify the characteristics of the construction projects that are critical in the occurrence of the risks. For that purpose, an in-depth literature review was conducted to extract characteristics of the construction projects in the first step of the study. Then, a questionnaire survey was prepared to collect expert opinions. Finally, a MATLAB script was developed in-house to perform a fuzzy AHP method to analyze the gathered data. The findings show that the contract-related characteristics, contract type, project value, and construction-related characteristics are the most critical characteristics of construction projects related to risk occurrence cases.
Keywords: Risk management, risk identification, project characteristics, fuzzy AHP, MATLAB.

1. INTRODUCTION

The performance of the construction industry (CI) has been continuously criticized by authorities such as governmental agencies and professional chambers [1]–[3]. Many studies have also pinpointed that the CI shows the worst performance among all industries in terms of productivity and efficiency [4], [5]. Moreover, due to the emergence of intense global competition, the construction companies cannot achieve their long-term expectations by implementing traditional business models that are considered ineffective and unproductive in the international market [6]. Therefore, construction companies should revise and refine their construction management processes to be able to compete and survive in the market.

Dynamic, random, turbulent, and project-based nature of the CI is one of the well-known reasons for low performance of construction companies, since these characteristics can cause high uncertainty and a high risk environment. This risky environment leads to the requirement of effective implementation of risk management, as construction companies can identify all possible risks and take necessary measures only via effective risk management.

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Risk management is a repetitive process, and it is crucial to eliminate and control the risks [7]. The first step of this process is identifying risk factors, followed by an assessment of risk impacts on the project. The last step is determining the necessary strategies to minimize the negative consequences of the risks [8]–[10]. Risk identification is the first and most crucial step in risk management [9], since all subsequent phases (assessment, analysis, and responding) are conducted based on identified risk factors. In other words, the further steps of risk management become ineffective when risks are identified improperly. However, due to limited information about the construction projects at their initial stages because of high uncertainty and vagueness, identifying all possible risks is a challenging task. Therefore, many methods were proposed in the literature to identify risks more accurately. However, in practice, the risks are generally identified by using the experts' experience and their judgments. In other words, decision makers apply the lessons learned from past projects to their current projects to identify the risks when the projects are similar. Therefore, instead of developing complex mathematical models, understanding risk attitudes and behaviors of the risk managers can be more effective while developing a model for a risk identification process[11].

This is a reliable approach, since although each project is a unique and temporary endeavor, they still have similar features such as the structure of teams, processes, tools, and skills, even if the projects differ with respect to macro terms such as the site, context, client requirements [12]. In particular, similar projects tend to face similar risks, and decision makers can use post-project risk event histories to give more reliable decisions in similar projects [13]. However, exploiting the most similar past projects for forthcoming projects is crucial at this point, since current risk management practices fail to offer a systematic mechanism to determine the similarity between the projects [14]. Therefore, risk managers use their judgments to find similar cases. The bottleneck of this approach is that there are many characteristics of a construction project, and each of them has various effects on the risk occurrence. Thus, risk managers should identify the most similar projects based on these characteristics. Otherwise, the risks identified by considering the past projects based on the similarities of other project characteristics that have limited or no effects on the risk occurrence can lead to misleading conclusions about the probable risks.

Project characteristics can be defined as unique project features that can be used to describe (or represent) a project. The project value, contract type, and total construction area can be considered among the examples of project characteristics. Despite all the challenges and benefits of the risk identification process mentioned above, there has not been any direct link established between project characteristics and project risks yet. Several researchers that have studies related to risk management based on Case-Based Reasoning methods (CBR), such as Fan et al. [15] and Lu et al. [16], emphasized the relationship between project characteristics and project risks. However, their focus was the CBR application on risk management rather than the sole effects of project characteristics on the occurrence of project risks. In addition, a limited number of project characteristics were considered for risk identification in these studies. Thus, to fill this gap in the literature, this study aims to (1) determine the characteristics of the construction projects (2) and the effects of these characteristics on the occurrence of the risks based on the Fuzzy AHP analysis. This study is beneficial for practitioners and academicians. The practitioners can understand which project characteristics are more important to lead to the occurrence of risks so that they can determine the most appropriate projects to identify the risks. In addition, the academicians can use the findings of this study to develop new models for risk identification.

In the remaining part of this paper, a comprehensive literature review is presented in the next section. In section 3, the methodology used in this research paper is presented while section 4 includes the results and discussion. Finally, the conclusion is presented.

2. THEORETICAL BACKGROUND

2.1. Characteristics of Construction Projects

The previous studies identifying project characteristics are summarized in this section and presented in Table 1.

Table 1. Summary of the literature review

Reference	Brief description of the study
Bing and Tiong [17]	The authors focused on the risks of Chinese projects performed via joint ventures, and they identified 25 risks related to the characteristics of the projects derived from both external and internal groups. The project value, location of the project, contract value and project duration are the project characteristics indicated in this study. However, the effect of each characteristic on the risk occurrence was not determined. Furthermore, only a few numbers of project characteristics were proposed, which failed to represent the project holistically.
Ling et al. [18]	They investigated the effects of construction project characteristics on the performance of Design-Build and Design-Bid-Build projects. The gross floor area of the project, payment mode to the contractor, and type of the building are the project characteristics investigated in this study.
Ozorhon et al. [19]	They investigated the impact of 13 project characteristics on international joint ventures. The results of structural equation modeling (SEM) provide evidence that project characteristics have a great impact on the performance of international joint ventures.
Han et al. [20]	They tried to establish a link between project characteristics and project's profitability. The study suggested that the climate and weather conditions, technical complexity of the project and clarity of the contract document are the project characteristics that can affect profitability.
Cho et al. [21]	The authors investigated the effect of project characteristics on the performance of a construction project. The authors classified project characteristics into two groups as the project environment and project participants. The analysis was performed using SEM.
Eybpoosh et al. [22]	They aimed to identify risk paths in international construction projects by using the SEM method. The authors proposed the project type, region, project size, project delivery system and contract type as the characteristics of construction projects.
Fidan et al. [7]	The authors identified new project characteristics through a case study (a residential construction project in Dubai). They considered the new project characteristics as the robustness in the project design, project construction, external project condition, project management and project contract conditions. Besides, 14 sub-characters were proposed for these characteristics.
Nguyen et al. [23]	They quantified project complexity using 12 project characteristics. The effects of the project characteristics on project complexity were ranked via descriptive analysis.
Liu et al. [24]	They extracted six project characteristics through a literature review, and the effect levels of project characteristics on the project delivery systems were determined by analyzing the data collected from a questionnaire survey.
Nguyen et al. [25]	The effect of project complexity on the cost and schedule performance was investigated in this study. Project complexity was measured through a set of project characteristics. These characteristics include the project size in terms of capital, the ambiguity of project scope, climate conditions, geological conditions, and the accessibility of the site.
Penaloza et al. [26]	They developed a system based on project characteristics, named as the company size, project type and construction area to monitor the complexity and resilience of construction projects.
Luo et al. [27]	The authors linked the project complexity to project success via a hybrid SEM-FCM method. The results indicated that information, goals, and environmental complexities are negatively correlated with project success.

2.2. Fuzzy set theory and fuzzy AHP

Many decision-making tasks cannot be quantified due to the existence of a high level of complexity in these tasks. However, the human brain can handle complex problems by using imprecise knowledge rather than precise knowledge. This mechanism of the human brain is the main inspiration of the Fuzzy set. The Fuzzy set theory proposed by Zadeh [28] works similarly to human reasoning, which is capable of generating decisions under the circumstances of approximate information and uncertainty. The specific purpose of the fuzzy set theory is to mathematically represent uncertainty and vagueness to provide a formalized tool for dealing with the imprecision. In other words, the fuzzy set theory can deal with the vagueness of human thought, whereas traditional computing systems necessitate precise and certain knowledge that is not available in many real-world problems. In addition, the fuzzy set theory also helps to simplify many engineering problems as knowledge can be expressed more naturally by using fuzzy sets. Especially, the use of linguistic variables is one of the critical aspects of the fuzzy logic application to express the problem in a more natural way, since linguistic variables such as "large" and "medium" are used rather than the numbers (E.g., Likert's scale) [29]. Therefore, the respondents can explain their opinions clearer compared to giving numerical answers.

The analytic hierarchy process (AHP) was developed by Saaty [30] and became one of the most popular multi-criteria decision-making methods [29], [31], [32]. The method decomposes a decision-making problem into a system of hierarchies of objectives, attributes (or criteria), and alternatives. The mechanism of AHP includes decompositions, pairwise comparisons, and priority vector generation and synthesis. The AHP is a reliable tool; however, it still cannot reflect the vagueness of the human thinking style. Whereas, the Fuzzy set theory can combine any "crisp" methodology or theory by fuzzifying these definitions to include the human thinking style. Therefore, the Fuzzy AHP was developed to solve hierarchical problems [33]. In essence, both AHP and Fuzzy AHP methods are used to capture experts' opinions, and the Fuzzy AHP handles the impreciseness of the humans' judgments in a more effective way [34].

3. METHODOLOGY

This research was undertaken to determine the effects of construction projects' characteristics on the occurrence of project risks. Accordingly, the exploratory and qualitative methodology was followed in this study to exploit the knowledge from other sources. Literature reviews, case studies, questionnaire surveys, hierarchical clustering, and multidimensional analysis are among the examples of this methodology [35]–[37]. In particular, an in-depth literature review was conducted to extract the characteristics of construction projects, which can lead to the occurrence of risks. Then, expert opinions were gathered through a questionnaire survey to determine the effects (namely weights) of each characteristic of a project on the occurrence of the project risks. Finally, the data were analyzed by using Fuzzy AHP. All these steps were illustrated in Figure 1.

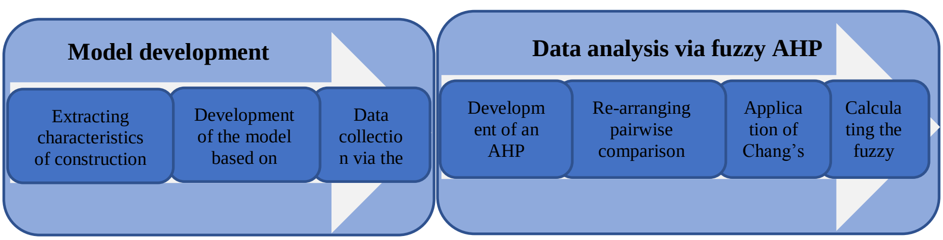

Figure 1. Research Methodology

3.1. Literature review and data collection

At the initial stage of this study, the characteristics of the construction projects were identified by conducting a literature survey via Google Scholar and Scopus. The literature review indicated that a limited number of studies that investigated the relationship between project characteristics and the risk occurrence have been conducted as stated above. Moreover, a limited number of characteristics were proposed in these studies. Therefore, the scope of the literature review was widened to extract as many project characteristics as possible. In addition, some studies proposed the same characteristics under different names. Therefore, to refine the list, these characteristics were identified and merged with each other. Finally, a list of 12 main project characteristics and 14 subproject characteristics was extracted from the studies of researchers such as Bing and Tiong [17], Ling et al. [18], Han et al. [20], Cho et al. [21], Eybpoosh et al. [22], Fidan et al. [7], Nguyen et al. [23], Liu et al. [24] and Penaloza et al. [26], and these characteristics were represented in Table 2.

Table 2. Characteristics of construction projects.

Main Characteristics	Sub-characteristics
Project type	-
Country	-
Project delivery system	-
Project value	-
Duration	-
Total construction area	-
Contract type	-
Design-related characteristics	D1: Complexity of design
	D2: Completion level of design
	D3: Constructability level
	D4: Quality of design
Construction-related characteristics	C1: Complexity of construction methods
	C2: Accessibility of the site
External conditions-related characteristics	E1: Comprehensiveness of geotechnical
	E2: Climate & weather conditions
Project management-related characteristics	P1: Strictness of quality management
	P2: Strictness of environmental management
	P3: Strictness of safety management
	P4: Strictness of project management
Contract-related characteristics	CC1: Vagueness in contract clauses
	CC2: Clarity of contract documents

In the second stage of this study, a questionnaire survey was prepared. This questionnaire consisted of three parts. In the first part, the respondents provided information about themselves and their companies. The second part included the pairwise comparisons of the main criteria. In the third part, respondents completed the pairwise comparisons of sub-criteria. In addition, all pairwise comparisons were made based on linguistic variables. The use of linguistic variables allowed experts to reflect their opinions about the effect of project characteristics on risk occurrence more precisely, in turn, ambiguity is eliminated [38].

Another crucial point of this study is the determination of the sample size to reveal the reliability of the study. Saaty and Özdemir [39] stated that specific and strict rules do not exist for the required sample size for AHP surveys. However, experts should be chosen from different constituencies to form political expediency. In addition, the AHP does not mandatorily necessitate a large sample size to give reliable results [40], since reliable results can be obtained even when one expert participated in the surveys [39]. By contrast, a large sample size may lead to unreliability due to the *cold-called* respondents [41]. In addition, a large sample size can even increase the degree of inconsistency [42].

Although a large sample size is not a prerequisite for reliable findings, the respondents who participated in AHP studies should be well-experienced to obtain reliable results. In other words, the quality of the data is more important than the quantity of the data. In this study, 15 experts were selected carefully using judgment sampling and their demographic information, which is shown in Table 3. Table 3 shows that the experts of this study have high experience in risk management in construction projects. In addition, they have major roles in their companies, and they also have high international experiences.

Table 3. Demographics of the Respondents

<table>
<tr><th>Sample Specifications</th><th colspan="4">Counts and Percentages</th></tr>
<tr><td rowspan="2">Parent organization</td><td>Client</td><td colspan="2">Main Contractor</td><td>Sub-contractor</td></tr>
<tr><td>4 (%26.66)</td><td colspan="2">10 (%66.66)</td><td>1 (%6.66)</td></tr>
<tr><td rowspan="2">Size of the organization</td><td>Small</td><td colspan="2">Medium</td><td>Large</td></tr>
<tr><td>2 (%13.33)</td><td colspan="2">3 (%20)</td><td>10 (%66.66)</td></tr>
<tr><td rowspan="2">Experience of the organization in International CI</td><td>0-20</td><td colspan="2">20-50</td><td>50-100</td></tr>
<tr><td>8(%53.33)</td><td colspan="2">4(%26.66)</td><td>3(%20)</td></tr>
<tr><td rowspan="2">Experience of the organization</td><td>0-20</td><td colspan="2">20-50</td><td>50-100</td></tr>
<tr><td>4(%26.66)</td><td colspan="2">5(%33.33)</td><td>6(%40)</td></tr>
<tr><td rowspan="2">Experience of the respondent</td><td>0-10</td><td colspan="2">10-15</td><td>15-30</td></tr>
<tr><td>4(%26.66)</td><td colspan="2">7(%46.66)</td><td>4(%26.66)</td></tr>
<tr><td rowspan="2">Experience of the respondent in risk management</td><td>0-5</td><td colspan="2">5-10</td><td>10-25</td></tr>
<tr><td>5(%33.33)</td><td colspan="2">3(%20)</td><td>7(%46.66)</td></tr>
<tr><td rowspan="2">Education level</td><td>BSc.</td><td colspan="2">MSc.</td><td>Ph.D.</td></tr>
<tr><td>3(%20)</td><td colspan="2">9(%60)</td><td>3(%20)</td></tr>
<tr><td rowspan="2">Role of the respondent</td><td>Coordinator/CEO</td><td>Planning Specialist</td><td>Tendering Specialist</td><td>Academician</td></tr>
<tr><td>6(%40)</td><td>3(%20)</td><td>3(%20)</td><td>3 (%20)</td></tr>
</table>

Another benefit of a small sample size is the fact that data can be gathered through face-to-face interviews. This is crucial for collecting reliable data for the fuzzy AHP since most of the respondents can have problems in filling the questionnaires appropriately when they have limited information about the fuzzy AHP. Therefore, the consistency level can be a problematic issue in these studies. Individual meetings were set-up, and the questionnaire was explained to each of the respondents. Firstly, the respondents performed pairwise comparisons between the main criteria. In this matrix, the effects of the main criteria on the risk occurrence were compared based on six linguistic variables, namely, Just equal, Equally Important, Weakly Important, Moderately Important, Strongly More Important, Extremely Important. Secondly, pairwise comparison matrices were prepared for sub-criteria by using the same linguistic variables. In other words, five matrices were prepared at the end of this stage. Then the results were analyzed by using the Fuzzy AHP.

3.2. Methodology followed throughout the analysis

This section includes the mathematical background of the Fuzzy AHP and the analysis results. The steps of Fuzzy AHP and the mathematical formulations are presented as follows.

Step 1. *Development of an AHP structure:* As stated above, project characteristics were extracted from the literature, and these characteristics were used to propose a model that shows the relationship between the project characteristics and occurrence of risks. A typical AHP model structure includes main criteria and sub-criteria, which are the characteristics of the projects in this study. Namely, some characteristics were grouped with respect to their similarities, such as design-related characteristics and construction-related characteristics. Figure 2 shows the final structure of the AHP.

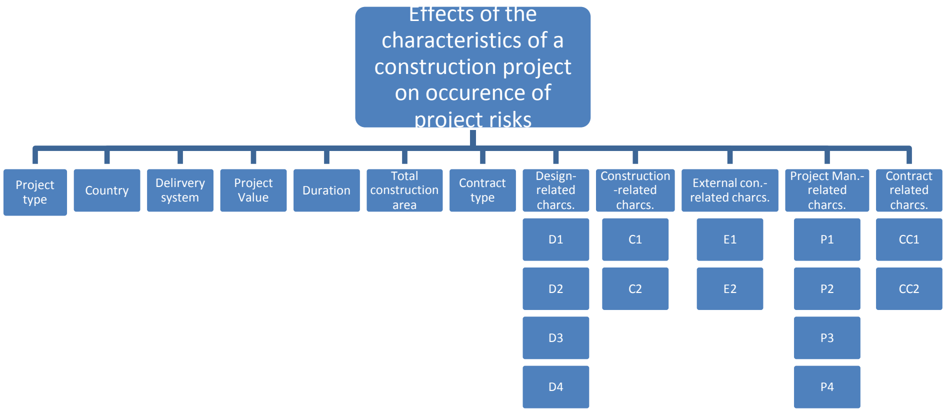

Figure 2. AHP model structure

Step 2. *Re-arranging pairwise comparison matrices by using fuzzy numbers:* This step can also be called fuzzification. Namely, pairwise comparison matrices were filled by the experts using linguistic variables, and these pairwise comparisons were re-arranged using fuzzy numbers given in Table 4. In other words, these matrices were fuzzified. Triangular fuzzy numbers were used for fuzzification in this study. Three parameters (*l, m, u)* are used to define the triangular fuzzy numbers. "*l*" denotes the smallest possible value, "*m*" indicates the most likely value, and "*u*" denotes the largest possible value that describe a fuzzy event.

Table 4. Triangular fuzzy scale (derived from Chang [33])

Linguistic variables	Crisp Number	Triangular fuzzy number	Triangular fuzzy reciprocal number
Just Equal	1	(1, 1, 1)	(1, 1, 1)
Equally Important	2	(1/2, 1, 3/2)	(2/3, 1, 2)
Weakly Important	3	(1, 3/2, 2)	(1/2, 2/3, 1)
Strongly More Important	4	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Very Strongly More Important	5	(2, 5/2, 3)	(1/3, 2/5, ½)
Absolutely More Important	6	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)

Step 3. *Application of Chang's extent analysis method:* At the previous stage, all matrices were fuzzified. Since there is no commercial software for the application of the fuzzy AHP, a MATLAB script was coded in-house to solve fuzzy AHP matrices by following Chang's extent analysis method. This method was used to find the weights of each characteristic. Chang [33]'s extent analysis is a method of using crisp mathematical concepts to address fuzzy quantities. Let $X = (x_1, x_2, x_3, \dots \dots \dots, x_n)$ be an object set and $U = (u_1, u_2, u_3, \dots \dots \dots u_{m)}$ be a goal set. Chang's extent analysis method dictates that extent analysis for each goal, g_i is performed, respectively. Firstly, the value of the fuzzy synthetic extent should be calculated as follows:

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \times \left[\sum_{j=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}; \quad (1)$$

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right); \quad (2)$$

To calculate $\left[\sum_{j=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}\right]^{-1}$, perform the fuzzy addition operation of $M_{gi}^{j}(j = 1, 2, \dots \dots \dots, m)$ values such that:

$$\left[\sum_{j=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}\right] = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \quad (3)$$

And then the inverse of the vector in Eqn (3) is calculated as follows:

$$\left[\sum_{j=1}^{n} \sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \left(\frac{1}{\sum_{j=1}^{n} u_i}, \frac{1}{\sum_{j=1}^{n} um_i}, \frac{1}{\sum_{j=1}^{n} l_i}\right) \quad (4)$$

Finally, the value of the fuzzy synthetic extent is calculated, and the degree of possibility was obtained using the value of the fuzzy synthetic extent. The following equations, Eqn (5), Eqn (6), Eqn (7) are used to calculate probability values. After obtaining the possibilities, the weight vectors were calculated, and eventually, the normalized weights vector was calculated to determine the weight of each project feature.

The degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M1 = ((l_1, m_1, u_1)$ is defined as:

$$V(M_1 \geq M_2) = sup[\min(\mu_{M1}(x), \mu_{M2}(y))] \quad (5)$$

When a pair (x, y) exists such that $x \geq y$ and $\mu_{M1}(x) = \mu_{M2}(y) = 1$, then $V(M_1 \geq M_2) = 1$. Therefore, the degree of the possibility is as follows, since M_1 and M_2 are convex fuzzy numbers:

$$V(M_1 \geq M_2) = 1, \text{ if } m_1 \geq m_2; \quad (6)$$

Otherwise;

$$V(M_1 \geq M_2) = htg\ M_1 \cap\ M_2 = \frac{l_1 - u_2}{(m_2 - u_{2) - (m_1 - l_1)}} \quad (7)$$

Both M_1 and M_2 values are needed to make the comparison given above.

The degree of possibility for a convex fuzzy number to be greater than k convex fuzzy numbers M_i (i=1, 2, ……., k) can be defined by Eqn (8)

$$V(M \geq M_1, M_2, \ldots \ldots . M_k) = V[(M \geq M_1)] \text{ and } (M \geq M_2) \text{ and} \ldots \ldots \text{and } [(M \geq M_k)] = minV(M \geq M_i); \quad i = 1, 2, 3, \ldots \ldots \ldots, k \quad (8)$$

Assuming that, $d'(A_i) = \min V(S_i \geq S_k)$ for =1, 2, …..n; k≠I, the weigh vector (W) is calculated by using the following formula:

$$W' = (d'(A_1), (A_2), \ldots \ldots \ldots d'(A_n))^T \quad (9)$$

Where: $A_i (i = 1, 2, 3, \ldots \ldots \ldots, n)$ are n elements.

The last step is the normalization which is calculated using the equation given below:

$$W = (d(A_1), d(A_2), \ldots \ldots \ldots \ldots \ldots \ldots d(A_n))^{\ T} \quad (10)$$

Step 4. *Calculating the fuzzy Eigen Value:* After Chang's extent analysis was applied to the pairwise comparison matrices, the Eigen value of each matrix was calculated to check the consistency of these matrices. A consistency check is another strength of the AHP method that no other multi-criteria decision-making method can achieve. The consistency of each matrix is checked by using the consistency index (C.I.) and consistency ratio (C.R) as proposed by Saaty [30].

The consistency of a matrix is evaluated by using Eqns (11) and (12):

$$C.I. = \frac{\lambda_{max} - n}{n - 1}; \quad (11)$$

$$C.R = \frac{C.I.}{R.I.} \quad (12)$$

Where: λ_{max} is the largest Eigen value of the comparison matrix, n is the dimension of the matrix, and R. I. is the random consistency index of the matrix chosen from Table 5.

Table 5. RI of random matrices [43]

n	1	2	3	4	5	6	7	
RI	0	0	0.52	0.89	1.12	1.26	1.36	
n	8	9	10	11	12	13	14	15
RI	1.41	1.46	1.49	1.52	1.54	1.56	1.58	1.59

According to Saaty [30], the overall consistency ratio should be equal to or less than 10%. Otherwise, the answers of the experts are considered to be inconsistent [44]. In such a case, the decision makers must check their answers.

Table 6. The normalized weight of criteria and sub-criteria

Main Criteria	Normalized Weights of Criteria	Ranks	Sub-criteria	Normalized Weights of the Sub-criteria	Ranks
Project type	0.0741	9	-	-	-
Country	0.0873	7	-	-	-
Delivery system	0.0751	8	-	-	-
Project value	0.0929	3	-	-	-
Duration	0.0727	10	-	-	-
Total construction	0.0632	11	-	-	-
Contract type	0.0962	2	-	-	-
Design-related characteristics	0.0620	12	D1: Complexity of design	0.16	4
			D2: Completion level of design	0.25	3
			D3: Constructability level	0.31	1
			D4: Quality of design	0.29	2
Construction-related characteristics	0.0917	4	C1: Complexity of construction methods	0.51	1
			C2: Accessibility of the site	0.49	2
External conditions-related characteristics	0.0891	6	E1: Comprehensiveness of geotechnical investigation	0.77	1
			E2: Climate & weather conditions	0.23	2
Project management-related characteristics	0.0899	5	P1: Strictness of quality management requirements	0.27	2
			P2: Strictness of environmental management requirements	0.21	4
			P3: Strictness of safety management requirements	0.24	3
			P4: Strictness of project management requirements	0.28	1
Contract-related characteristics	0.1058	1	CC1: Vagueness in contract clauses	0.66	1
			CC2: Clarity of contract documents	0.34	2

Since in-house codes were written for this study, to avoid any coding errors, the computational accuracy was tested using the data presented by Chang [33], Işık and Aladağ [45]. This verification showed that the analysis conducted with coded MATLAB script gave the same results as these studies; therefore, the codes were determined as reliable. In addition, the consistency check feature was also added to the system, and all matrices were found consistent. The consistency ratios of the matrices were 0.0077, 0.0076 and 0.0071 for the pairwise comparisons of the main criteria, design-related characteristics, and the project management characteristics, respectively. It should be noted that consistency can be checked only when the matrix size is greater or equal to 3 [30]. Thus, there are no consistency measures for construction-related characteristics, external-related characteristics, and project-management related characteristics. Finally, the weights of the project characteristics obtained as a result of fuzzy AHP analysis were given in Table 6.

4. DISCUSSION OF FINDINGS

Weights of project characteristics on the occurrence of risks were given in Table 6. These results indicate that each project characteristic has a different weight. This finding can support the hypothesis of this study, stating that the characteristics of a project have different effect levels on risk occurrence. Thus, the risk managers should consider the most effective project characteristics to identify the projects that are similar to their projects, and they should use previous experiences gained in these projects rather than relying solely on their judgments.

Based on the ranks of the project characteristics shown in Table 6, the most effective project characteristic on risk occurrence is determined as "contract-related characteristics" with a weight of 0.1058. Cevikbas and Koksal [46], [47] also asserted that contractual requirements embodied in the general conditions of contracts can be considered as potential sources of risks. In addition, Dikmen et al. [13] identified that the contract conditions are one of the important reasons for risks in construction projects. Similarly, Ustinovichius [48] stated that the specifications of contracts and their requirements have the potential to lead to risks. Therefore, this result came as no surprise since deficiencies in a contract subsequently can cause uncertainties throughout the project, which lead to risks [20]. In addition, one of the purposes of the contracts is to clarify the scope of the projects. In this context, the contracts should eliminate all ambiguities in the scope of the projects. However, when the ambiguities about the project scope exist in the contract, more and more design changes will be confronted during the construction process, and thus cost and time overruns are inevitable due to the extensive reworks [23]. Consequently, it is evident that there is a direct relationship between the contract conditions and risk occurrence. Therefore, the similarity between the contract conditions should be considered during the process of determining similar projects that can be used to identify risks.

"Vagueness in contract clauses" obtained a higher score in the "contract-related characteristics" category compared to the "clarity of contract document" characteristic. Fidan et al. [7] highlighted the importance of "vagueness in contract clauses" with an example obtained via a case study conducted in Dubai. They stated that due to the vagueness in the contract, the contractors were confronted with many difficulties, such as regular changes of the position of the crane and coordination problems. Even this example shows that any kind of vagueness in the contract leads to the occurrence of unexpected risks. In addition, the parties involved in a project can understand the clauses in different ways due to the vagueness [49], which may lead to occurrence of risks as the responsibilities are not assigned to the parties clearly. Consequently, the similarities between the vagueness level in the contract clauses should be checked while identifying similar projects.

"Contract type" was rated as the second most important major project characteristic with a weight of 0.0962. The main reason for this finding can be that contract type is the term used to signify the differences in the contract structure or form, including compensation arrangements and especially risk allocation. For instance, Besaiso et al. [50] compared FIDIC and NEC in terms of risk management and allocation and concluded that these two contract types have different approaches and frameworks for risk management and allocation. Especially, risk allocation is an extremely important term since it indicates the amount of the risk taken by either the client or the contractor [51]. Thus, the amount of the risk taken by the company greatly varies with respect to the "contract type." Consequently, the risk managers should consider the contract type for determining the similarities between the projects.

"Project value," which can also be called contract value, is placed third in the order. This term might be considered as an important indicator of the complexity of a project, since high project value is often proportional to project complexity [24], and there is a direct relationship between the project complexity and complexity related risks [52]. In other words, construction companies take more risks when the complexity of a project increases. In addition, project complexity creates a network of interdependent risks [53]. In other words, an upstream risk can create numerous downstream risks; on the other side, several 'upstream' risks, which may belong to different categories, can lead to the emergence of a downstream risk [54]. In addition, project finance is another term associated with the project value, since companies must seek a sponsor to reach the required capital to carry out a project. This process, however, comes at a price. For instance, a company must be more careful about project's cash flow and other financial indicators to be able to pay all its liabilities. If not, project risks will eventually increase, and the project will become more vulnerable.

"Construction-related characteristics" obtained the fourth highest rank among the main criteria. The construction stage of a project involves numerous uncertainties. Therefore, it is usually associated with a high degree of risk due to the nature of the construction business activities, processes, environment, and organization [55]. Thus, these characteristics are some of the significant contributors to the risks of construction projects [56]. The complexity of the construction methods obtained a slightly higher score than the accessibility of the site. However, both characteristics could be considered as equally important due to the similarity of their scores. The importance of innovative and advanced methods has been increasing with the increase in the number of complex projects. However, innovative solutions consist of more uncertainties, since the solutions have been implemented in a limited number of projects, in other words, the experience level of the companies for applying these solutions is low. Therefore, innovative solutions can be risky and create unanticipated effects [57], and innovation is also perceived to be correlated with risky decisions and doubtful results [58]. Especially, innovation creation is highly correlated with high risk [59]. In addition, innovative and advanced methods require special machinery, special equipment, and highly qualified workforces. The availability of these resources can also lead to different risks. On the other hand, the accessibility of a site can also be an issue. Routes of a construction site must be appropriately designed in a way that smooth delivery of materials, safe machine operation, and relatively easy relocation of large objects are possible on the site [60]. Site planning has a direct impact on cost and construction progress in the event of unforeseen conflict [61]. Especially in urban areas, accessibility to the construction site can create uncertainties and risks. Therefore, enough attention should be paid to "construction-related characteristics" in the risk identification stage.

5. LIMITATIONS OF THE STUDY

Every study has limitations such as bias, variance, timing, or even errors originated from the research process. This study also has several limitations. The most important potential limitation of this study is elaborated as follows:

1. In this study, the views of the experts from Turkey were used to determine the weights of the project characteristics on the occurrence of the risks; thus, the findings of this study can be considered as local. However, all the respondents work at international construction companies, and they played active roles in the construction or bidding process of international projects. Therefore, the findings of this study could be used for the projects conducted in different parts of the world.

6. CONCLUSION

In this research, it is aimed to determine which project characteristics are more effective on the risk occurrence in the construction projects. Therefore, these characteristics can be used to determine the most similar projects which can be used for risk identification. For that purpose, initially, project characteristics were extracted by conducting an in-depth literature review. The initial list further refined by analyzing and merging the similar project characteristics proposed under different names by different authors. Then, a questionnaire survey was prepared, and the judgments of 15 respondents were gathered. All respondents have sufficient experience in both risk management and international construction projects. Therefore, the data obtained at the end of the survey can be considered as reliable. At the final step, the fuzzy AHP analysis was performed to determine the effects (namely weights) of each project characteristic on the risk occurrence. Fuzzy AHP methods were selected due to their versatility and reliability.

The results showed that each characteristic has a different effect level on the risk occurrence; therefore, finding similar cases without considering these differences does not enhance the accuracy and comprehensiveness of the risk identification process. Especially, the similarity in high ranked characteristics should be checked to find similar cases. The findings indicate that "contract-related characteristics" have the highest weights among major project characteristics. The main reason for this finding is that deficiencies in a contract subsequently lead to uncertainties in all remaining stages of the project. For instance, ambiguities in the contract are likely to cause either design changes or reworks, which may lead to the occurrence of new risks. The experts rated "contract type" as the second most important project characteristic that can contribute to the occurrence of the risks of the construction projects. Risk allocation can be one of the reasons for the importance of contract type, since "contract type" is one of the terms that dictate the amount of the risk taken by each stakeholder of the project. Another important project characteristic is "project value." "Project value" significantly associates with the project risks, since high project value usually indicates high project complexity and complicated financial structure.

This study can be used to assist risk analysts in terms of finding similarities between the construction projects. Thus, risk managers could identify the project risks more accurately by considering the risks that occurred throughout similar projects.

Acknowledgements

This work was supported by the Research Fund of Yildiz Technical University. (Project Number: FYL-2020-3823)

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