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Providing a Model For Assessing Risk Management Of Construction Projects With A Sustainable Development Approach: Case Studies Of Small-Scale Power Plants

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ABSTRACT

Economic growth in developing countries requires the implementation of infrastructural projects such as power plants, the sustainability of which plays an important role in the social, economic, and environmental development. Despite, these projects are always associated with uncertainties and risks due to features such as uniqueness, unspecified time, the need for specific equipment, correlation between different phases and so on. Therefore, in the present study, a small-scale power plants in Mazandaran was subjected to a case study by which the project risks were properly studied. By interviewing the experts associated with the construction of the power plant, 34 risks were identified and subsequently categorized into four categories of environmental, economic, social, and technical. Then, using the failure factor analysis method, their effects were evaluated, and critical risks were identified. In the next step, Fuzzy TOPSIS hierarchical analysis method was used to prioritize critical risks according to the project objectives in accordance with the PMBOK project management standard. After prioritizing the critical risks, in accordance with the real conditions of these projects, suggestions were made to respond and face the critical risks.

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1. Introduction

Construction projects have been executed over a long period and involve many stakeholders such as government agencies, designers, contractors, investors, and end-users, and have a great effect on society (Marrewijk, Clegg, Pitsis, & Veenswijk,2008; Chang, Soebarto, Zhao & Zillante, 2016). Therefore, the collaboration between stakeholders should be improved so that the product can provide the desired features and have a high level of sustainability (Kivilä, Martinsuo & Vuorinen, 2017; SILvIuS, Schipper, Van Den Brink & Planko, 2012). Therefore, the integration of sustainability into construction projects is one of the challenges of project management.

Sustainable construction satisfies the needs of sustainable development and can ensure economic development, social health and the reduction of the negative effects of construction on the environment (Czarnecki, Kaproń & Van Gemert, 2013; Li, Zhang, Ng & Skitmore, 2018) By focusing on environmental principles and resource efficiency, sustainable construction not only considers the environmental issue, but also tries to create a balance among the environmental, economic and social goals (Shi,Ye, Lu & Hu, 2014). Sustainable project management is a process whereby projects are controlled to ensure the achievement of sustainability goals based on environmental, economic and social principles (Silvius & Schipper, 2014). Although sustainable project management has been proposed for integration of sustainability into project management, it is not free from shortcomings. The studies having been conducted on the role of project management and planning show that its main objective is to reduce the uncertainty of projects (Laufer, Kusek, & Cohenca-Zall, 1997). Therefore, planning efforts can be considered a risk management tool in a hazardous environment (Zwikael & Sadeh, 2007).

Large-scale projects such as power plant projects are carried out in a dynamic and complex environment in such a way that uncertainty and risk are among their inherent characteristics. According to the 5th Edition of the *PMBOK. Guide*, project risk is "an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more project objectives such as scope schedule cost (PMI. 2008). According to the project risk management researchers, risk management covers all project management activities (Grey, 1995; Turner, 1995). Risk management is an important part of project management. The more accurately the uncertainties of a precise are analyzed, the more efficient and, of course, more practical its risk management will be (Patrick, Guomin & Jiayuan, 2007). The goal of risk management is to increase the probability of a project's success by providing systematic detection and evaluation of risk, and providing methods for avoiding or reducing risks and maximizing opportunities (Chapman & Ward, 2003).

So far, several standards have been proposed for risk management, including the Shape, Harness And Management Project Uncertainty (SHAMPU), Project Uncertainty Management (PUMA) (Del Cano & De la Cruz, 2002), and Active Threat & Opportunity Management (ATOM) (Hillson & Simon, 2007), but the most prominent and widely used standard of all is the PMBOK (Patrick, Guomin & Jiayuan, 2007).

This uncertainty has led to the failure of most of the country's projects to achieve their predetermined goals (time, cost, quality, etc.), which, in turn, has led to problems such as lack of economic justification of exploitation of projects, reduced efficiency and increased dissatisfaction among key stakeholders. There are a lot of problems in this industry and many studies have dealt with different ways to get out of these issues. Identifying the priority of risk factors through risk assessment is an important decision-making problem for the project construction management team. Le Wang proposed a model for assessing the risk of a construction project using the VIKOR and PFNP multi-criteria decision making framework (Wang, Zhang, Wang & Li, 2018). Kim and Kang presented a model for the analysis of the risk of construction costs (Kim & Kang, 2017). Han et al. predicted the integrated cash flow risk for construction projects (Han, Park, Yeom,. & Chae, 2014). Considering the dynamic nature of risks and constant changes in the projects, Nasirzadeh et al., provided a dynamic system-based approach that can simulate the impact of different risks on time, cost, and quality (Nasirzadeh, AFSHAR& KHAN, 2008). Ardeshir investigated the risks of projects for the construction of water transfer tunnels, specifically the risks associated with time, cost, quality and safety criteria using the fuzzy AHP approach (Ardeshir, Amiri, Ghasemi, & Errington, 2014). Using the fuzzy Bayesian model, Islam examined risk assessment in power plants projects (Islam & Nepal, 2016). Yelin et al. studied the critical risk factors affecting the implementation of public-private partnerships for waste-to-energy projects in China in a case study on 14 incineration plants (Xu, Chan, Xia, Qian, Liu, & Peng, 2015). Wang also used the neural network model to assess the risk management of power plant construction projects to create a risk assessment model and classify the risks that affects project goals during construction and even during operation (Wang, Niu, & Xing, 2010).
Doskocil & Lacko analyzed the key aspects of sustainable projects, namely, advanced risk management and project knowledge (Doskočil, & Lacko, 2018). Weiyao et al. evaluated the sustainability risks of large-scale hydropower projects and classified sustainability risks into three environmental, social and economic categories (Tang & Tu, 2018). Dongxiao et al. evaluated the sustainability of power grid construction projects. This project first identified 17 sustainability criteria and then classified them into four main technical, environmental, economic and social criteria and evaluated them using the improved TOPSIS method (Niu, Dai, Kang, Xue, Jin, & Song, 2018). Kim & Lee an investment decision-making process for sustainable development based on the profitability impact factors for overseas projects based on the value-at-risk (Kim & Lee, 2018). Despite the publication of numerous articles on risk management, there is little information available about its use in the real world (Lyons, 2002). According to various researchers, there is no comprehensive model for evaluating project risk reduction measures (Ben-David, Rabinowitz, & Raz, 2002). The purpose of this research is to evaluate risk with the sustainability approach. Sustainability in the environmental dimension means protecting and improving the capacity of production and renewal of environmental systems. In the economic dimension, sustainability means maximizing

the current net benefits and future economic development, while not reducing the quality of natural resources and related services. From the social point of view, sustainability means improving the people's quality of life and health status and ensuring access to the necessary resources in order to create an environment in which the freedom and equality of people's rights are protected. Given the definition of risk and the multidimensional nature of sustainability, sustainability risk involves considering the risks of the environment, economy and society (Tang & Tu, 2018). Since sustainable development is becoming more and more important for policymakers and decision-makers around the world, achieving the goals of sustainable development requires considering and integrating the sustainability and technical aspects, which have gradually been recognized by decision makers and policymakers (Ness, Urbel-Piirsalu, Anderberg & Olsson, 2007; Jeswani, Azapagic, Schepelmann & Ritthoff, 2010). Therefore, risks have been identified and categorized in the present paper into four environmental, economic, social, and technical sections.

2. Methodology

The relationship between the criteria affecting the risk of construction projects is very complex and usually one criterion affects other criteria. The evaluation and analysis of alternatives in different complex conditions, especially in the construction industry area which is affected by multiple criteria and varied alternatives, requires the use of quantitative techniques and mathematical models of decision-making. Although different mathematical decision techniques are available to contribute to the decision making process, these techniques are hardly used due to the limited time and their inherent complexity. In addition, various studies show that decision-making techniques related to risk management mainly focus on optimizing and improving a criterion. Therefore, it is necessary to study the methods in which several criteria, which are sometimes even contradictory, in planning simultaneously. This is why the present study has sought to present a different model for risk management in the construction of power plants projects using the Failure Modes and Effects Analysis (FMEA) and the Multiple Criteria Decision Making (MCDM) techniques in fuzzy environment.

2.1 Fuzzy Numbers And Fuzzy Sets

The fuzzy set theory was introduced by Professor Lotfizadeh. This theory is used in conditions of ambiguity and uncertainty. This theory is able to express many of the inaccurate concepts and terms with mathematical language and provide grounds for reasoning, inference, control, and decision making in conditions of uncertainty. According to this theory, $\tilde{A} = \{(x, \mu_{\tilde{A}}(x)) | x \in X\}$ is a fuzzy set in which x accepts the real values of the member of the R set and its membership function is as $\mu_{\tilde{A}}(x) :\rightarrow [0,1]$.

The most commonly used fuzzy numbers are triangular and trapezoidal fuzzy numbers. Triangular fuzzy numbers are most often used due to their simpler calculations. Triangular fuzzy numbers are also used in this study. A triangular fuzzy number A with linear membership function μA is defined as Equation (1), which is represented as a triangular fuzzy number (l, m, u). Figure 1 shows this membership function(Masoudnejad,Rayati & Gholampour, 2018).

$$\mu_A(x) = \begin{cases} (x-l)/(m-l), & l \le x \le m \\ (u-x)/(u-m), & m \le x \le u \\ 0, & otherwise \end{cases} \quad (1)$$

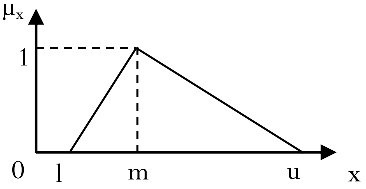


Figure 1. Triangular fuzzy number

If $\tilde{A}$ = (l_1, m_1, u_1) and $\tilde{B}$ = (l_2, m_2, u_2) are two triangular fuzzy numbers, the distance function d ($\tilde{A}$, $\tilde{B}$) is defined as Equation (2) (Masoudnejad,Rayati & Gholampour, 2018):

$$d(\tilde{A}, \tilde{B}) = \sqrt{\frac{1}{3}[(l_1 - l_2)^2 + (m_1 - m_2)^2 + (u_1 - u_2)^2]} \quad (2)$$

2.2 Failure Modes and Effects Analysis (FMEA)

The FMEA is an analytical technique based on the integration of two factors of technology and the experience of individuals to prevent the receiving an unwanted product by customers and prevent the risk of validity and reputation of the company (Besterfield, Besterfield-M Besterfield & Besterfield-S, 2003) which is widely used in construction and production industries in the various phases of the product life cycle and has increasingly been accepted in service industries (Kumru & Kumru, 2013).

Since the FMEA is about the failure modes and its effects, we need to define the term "failure". In terms of production, failure can be defined as "the inability of a design or a process to perform the desired task" (Kumru & Kumru, 2013). Most often, traditional FMEA uses a risk priority number (RPN) to assess the risk level. RPN is obtained by multiplying three factors of occurrence (O), severity (S) and detection (D) (Equation 10) (Kumru & Kumru, 2013). This method uses a score of 1 to 10 (1 for the best and 10 for the worst) to measure these three parameters.

$$RPN = O \times S \times D \quad (3)$$

Although the traditional FMEA method is widely used in research, this method has fundamental weaknesses.

To overcome the weaknesses in risk assessment and prioritization in relation to the traditional prioritization of the FMEA method, we have used the fuzzy logic in this method.

The term "fuzzy logic" gas come from the Lotfizade's fuzzy set theory. In 1965, Lotfizade proposed the fuzzy set theory and later proposed fuzzy logic based on the fuzzy set.

Tables 1, Table 2 and Table 3 show the ranks for severity, occurrence and detection, as well as linguistic terms and their corresponding triangular fuzzy numbers (Kumru & Kumru,2013).

Table 1 Definition of linguistic terms for occurrence(Tang & Tu, 2018)

Triangular fuzzy numbers	occurrence	linguistic terms
(0,1,3)	Above 66%	Very low
(1,3,5)	Between 33% and 66%	low
(3,5,7)	Between 10% and 33%	moderate
(5,7,9)	Between 1% and 10%	high
(7,9,10)	Below 1%	Very high

Table 2 Severity classification assessment criterion(Tang & Tu, 2018)

Triangular fuzzy numbers	Severe effect	linguistic terms
(0,1,3)	Without effect	Very low
(1,3,5)	With a low effect on the construction trend	low
(3,5,7)	Moderate effect on the construction trend	moderate
(5,7,9)	With high effect on the construction trend	high
(7,9,10)	With very high effect on the construction trend	Very high

Table 3 Definition of linguistic terms for detection / control(Tang & Tu, 2018)

Triangular fuzzy numbers	Detection/control	linguistic terms
(0,1,3)	The project team is able to identify a risk response strategy with a proven high impact on identifying risk events, controlling the underlying causes and outcome of the risk event.	Very low
(1,3,5)	The project team is able to identify a risk response strategy with a high probability of identifying risk events, controlling the underlying causes and outcome of the risk event.	low
(3,5,7)	The project team is able to identify a risk response strategy with a moderate probability of identifying risk events, controlling the underlying causes and outcome of the risk event.	moderate
(5,7,9)	The project team is able to identify a risk response strategy with a low probability of identifying risk events, controlling the underlying causes and outcome of the risk event.	high
(7,9,10)	The project team is unable to identify a risk response strategy with a capability of identifying risk events, controlling the underlying causes and outcome of the risk event.	Very high

The FRPN is not very efficient when the dimensions of failure (risk) affect several dimensions of an issue, because the FRPN is obtained based on the three criteria of occurrence, severity and control, and each one of these criteria by itself does not reflect the effects of all aspects of risk. In addition, there is dependency among different criteria in the real world. Therefore, we will use the Fuzzy TOPSIS Analytic Hierarchy Process to consider the impact of the risks on the different dimensions and objectives of the project and to consider the dependency among them.

2.3 *The Fuzzy TOPSIS Method*

The reason for using the TOPSIS method in the present study is that the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution Solution) method has appropriate mathematical foundations. This method deals with distances. TOPSIS chooses the option that has the most distance from the worst option and the least distance from the best option as the optimal option, and for this reason, and its mathematical basis, it is superior to other methods. Another advantage of this method is that it is a compensatory method. That is, the weight of all options and criteria is involved in the decision and no weight is ignored in this method.

The TOPSIS technique is one of the multi-criteria decision-making methods proposed by Hwang and Yoon in 1981 (Hwang & Yoon, 1981) developed by Yoon in 1987 (Yoon, 1987) and Huang et al. in 1993 (Hwang, Lai, & Liu, 1993.).
The fuzzy TOPSIS technique was first proposed by Chen to solve multi-criteria decision-making problems under uncertainty conditions (Chen, 2000). This technique has been used in many studies, and Fuzzy TOPSIS decision making methods have been developed in the electric power industry (Ervural, Zaim, Demirel, Aydin, & Delen, 2017) and finance (Tavana, Keramatpour, Santos-Arteaga, & Ghorbaniane, 2015) since the 1990s. Linguistic terms are used in this method to rank the alternatives and weights of the criteria, because the use of linguistic terms rather than numerical evaluation is more realistic and more tangible when dealing with unclassified and uncertain data, especially in modeling human judgments (Walczak, Rutkowska, 2017). We have

used linguistic variables and direct weighing methods in this study to evaluate the weights of the criteria and rank the alternatives. The linguistic variables and fuzzy triangular numbers corresponding to them, which have been used by decision makers (D = 1, 2 ..., K) for the weighing, were based the triangular fuzzy numbers introduced by Chen, as shown in Table 4 & 5 (Chen, 2000).

Table 4 Linguistic variables for the importance weight of each criterion

Linguistic variables	Triangular fuzzy numbers
Very low (VL)	(0.0, 0.0, 0.1)
Low (L)	(0.0, 0.1, 0.3)
Medium low (ML)	(0.1, 0.3, 0.5)
Medium (M)	(0.3, 0.5, 0.7)
Medium high (MH)	(0.5, 0.7, 0.9)
High (H)	(0.7, 0.9, 1.0)
Very high (VH)	(0.9, 1.0, 1.0)

Table 5 Linguistic variables for the ratings

Linguistic variables	Triangular fuzzy numbers
Very poor (VP)	(0, 0, 1)
Poor (P)	(0, 1, 3)
Medium poor (MP)	(1, 3, 5)
Fair (F)	(3, 5, 7)
Medium good (MG)	(5, 7, 9)
Good (G)	(7, 9, 10)
Very good (VG)	(9, 10, 10)

The Fuzzy TOPSIS method consists of the following steps (Chen, 2000):

Suppose that the decision group consists of K members. We can obtain the weights of the criteria and the ranking of the alternatives using equations 11 and 12. $\tilde{W}_j$ represents the weight of the j^th^ criterion.

$$\tilde{W}_j = \frac{1}{K}\left[\tilde{W}_J^1 + \tilde{W}_J^2, \ldots\ldots, \tilde{W}_j^k\right] \tag{4}$$

$$\tilde{x}_{ij} = \frac{1}{k}\left[\tilde{x}_{ij}^1 + \tilde{x}_{ij}^2 + \ldots. + \tilde{x}_{ij}^k\right] \tag{5}$$

In this matrix (D), $\tilde{x}_{ij}$ represents the rank of the ith alternative (i = 1, 2 ..,., m) based on the mth criterion (j = 1, 2 ..,., n), which is based on linguistic variables (Equation 13).

$$\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij}) \tag{6}$$

Step I: Equation 14 shows the decision matrix of the criteria and alternatives:

$$\tilde{W} = \left[\tilde{W}_1, \tilde{W}_2, \ldots\ldots, \tilde{W}_n\right] \tag{7}$$

Step II. Then, the fuzzy decision matrix must be converted to a comparable scale and be normalized. There are several methods for normalization, but Chen has proposed a linear normalization method. Thus, we can use equations 16 and 17 to normalize the profit and cost criteria.

$$\tilde{R} = \left[\tilde{r}_{ij}\right]_{m\times n} \tag{8}$$

$$\tilde{r}ij = \begin{cases} \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right), & j \in B \ \ , c_j^* = \max c_{ij} \ if \ j \in B \\ \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right), & j \in C \ \ , a_j^- = \min a_{ij} \ if \ i \in c \end{cases} \tag{9}$$

Step III: Now, we can obtain the fuzzy weighted normal matrix using Equation 16.

$$\tilde{V} = \left[\tilde{v}_{ij}\right]_{m\times n}, \quad i = 1,2,\ldots,m, \quad j = 1,2,\ldots.,n \tag{10}$$

If $\tilde{v}_{ij} = \tilde{r}_{ij} . \tilde{w}_j$

Step IV: The positive ideal (FPIS, A +) and the negative ideal solution (FNIS, A-) is obtained using equations 21 and 22.

$$A^* = \left(\tilde{v}_1^*, \tilde{v}_2^*, \ldots., \tilde{v}_n^*\right) \tag{11}$$

$$A^- = \left(\tilde{v}_1^-, \tilde{v}_2^-, \ldots., \tilde{v}_n^-\right) \tag{12}$$

Here, $\tilde{v}_j^- = (0,0,0)$, and $\tilde{v}_j^* = (1,1,1,)$.

Step V: The distance between the ith alternative, or the positive ideal (A +) and negative ideal (A-) can be obtained using equations 23 and 24, and the distance between the two triangular fuzzy numbers is calculated from Equation (2).

$$d_i^* = \left\{\sum_{j=1}^{n} d\ \left(\tilde{v}_{ij}, \tilde{v}_j^*\right)\right\} \quad i = 1,2,\ldots,m,\ j = 1,2,\ldots,n \tag{13}$$

$$d_i^- = \left\{\sum_{j=1}^{n} d\ \left(\tilde{v}_{ij}, \tilde{v}_j^-\right)\right\} \quad i = 1,2,\ldots,m,\ j = 1,2,\ldots,n \tag{14}$$

Step VI: Now using Equation 25, we can calculate the relative closeness coefficient of the ith alternative (CCi).

$$CC_i = \frac{d_i^-}{\left(d_i^* + d_i^-\right)}, \quad i = 1,2,\ldots,m\ ,\ 0 \le cl_{i+} < 1 \tag{15}$$

The ranking of alternatives is arranged in a descending order based on the closeness coefficient of CCi. The best alternatives include the closest alternative to the FPIS and the farthest alternative from it. In other words, the greater the relative closeness coefficient, the more ideal its corresponding alternative will be.In the proposed model of the present study, to manage risk in power plant projects, first using the failure technique and impact analysis and considering the criteria of probability of occurrence, impact intensity and control, risks in four sectors: environmental, economic, social and Technical, identified and classified, and critical risks identified. Then, the critical risks were evaluated according to the studied criteria using TOPSIS method in a fuzzy environment and during that the weight of the criteria was determined. In the next step, the risk ranking was determined according to the studied criteria in a fuzzy environment. The framework of the proposed model is presented in Figure 3.

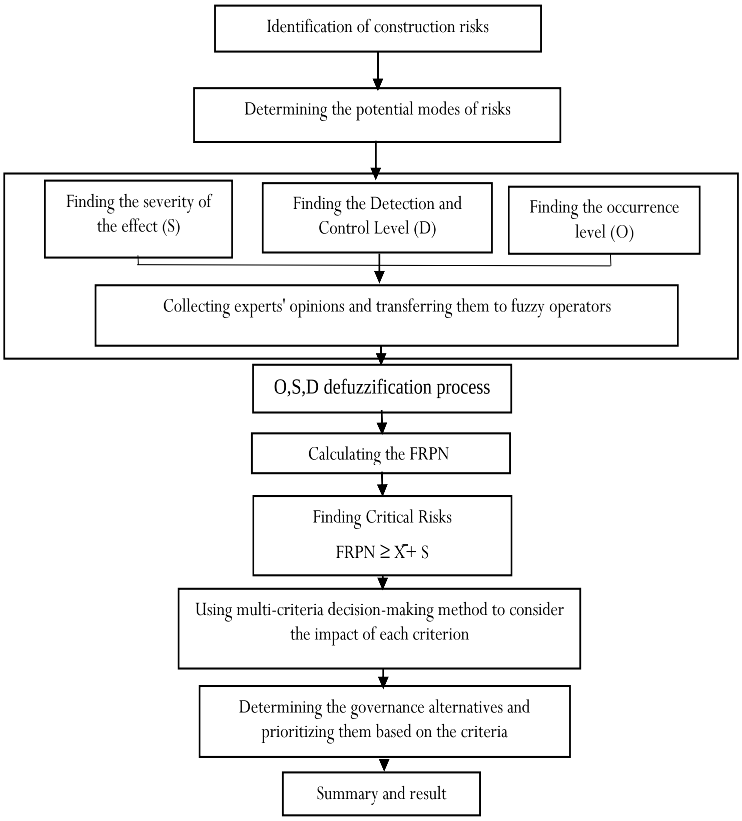


Figure 3 The conceptual model of risk assessment and management

3. Case Study

Today, the power industry is considered the engine of growth and development of other sectors. This industry is a dynamic and influential industry due to its underlying role and its close relationship with the factors affecting economic growth, and an increase in its productivity and efficiency is, therefore, of great importance. The power generation sector, which is the power plant, is one of the most important and cost-effective sectors of the power industry.

The purpose of this study is to provide a model for risk management of construction projects, with a sustainable development approach. To this aim, we first detected the risks existing in the project and then, using the FMEA Fuzzy method, we prioritized the risks and determined the critical ones. Having identified the critical risks, we used the multi-dimensional decision-making technique to assess their impact on the project's goals, because, as stated earlier, the RPN is not very effective when the risks affect several dimensions of the project's objectives. Besides, there is a dependency among different goals. Multi-criteria decision-making is a set of methods and procedures that try to make an analysis on several - most often inconsistent- indices or criteria to select an ideal alternative or prioritize the alternatives. We used the TOPSIS FUZZY technique in the present study so as to solve the decision-making problem. This method, like other decision-making methods, has three levels of goal, criteria, and alternatives. The purpose of the research is to " Provide a model for risk management of construction projects, with a sustainable development approach ". In the proposed model, the critical risks derived from the FMEA were considered the "alternatives", as shown in Table 8. The effective criteria for project goals were also selected based on the PMBOK project management standard and experts' views.

The book "Project Management Body of Knowledge (PMBOK)" was prepared by the Project Management Institute (PMI) Institute, which is the most well-known global reference for project management. PMBOK is the most popular standard in project management and is the most commonly used criterion for the design and evaluation of project management systems. Many of the most common definitions, terms and classifications that are used today in project management are taken from this standard. In other words, it is a common global language in project management. This standard is classified in the sixth edition in ten areas including project integration management, project scope management, project schedule management, project cost management, project quality management, project resource management, project communications management, project risk management, project procurement management and project stakeholder management, which have been regarded as the basis for this research. According to the studies and interviews conducted with the industry experts, the most important and effective goals of the project under study include project schedule management, project cost management, project quality management and project procurement management. Table 6 summarizes each of these areas in accordance with the PMBOK standard.

Table 6 Description of the most effective goals of the project

The most effective goals of the project	Definition	Code
Project schedule management	This includes the processes needed for the full project schedule management.	C_1
Project cost management	This includes the processes of budget planning, financing, cost management and control until the project is completed in the approved budget.	C_2
Project quality management	This includes processes to ensure fulfillment of the project stakeholders' needs based on the quality that has been committed.	C3
Project procurement management	Processes needed to access goods and services outside the project team.	C4

4. Finding and Discussion

Risk detection is a major step in the risk management process without which it is impossible to carry out other steps. There are various techniques for identifying project risks. There is not only one solution as the best way to identify project risks, but a combination of different techniques should be used (Kasap & Kaymak, 2007).

We have used a hybrid approach in this research for identifying risks in the project under study. Some of the tools used include an extensive review of the studies related to risk detection, backgrounds of previous projects, various interviews with experts, and holding brainstorm sessions. Considering the large number of risks in power plants projects on the one hand and the limited resources of the organization for risk management on the other, these risks must be prioritized and critical ones must be identified. For this purpose, the researchers performed risk assessment was based on the brainstorm method after the formation of the decision-making team. Based on this method, the group of contractors, who played the most important role in the implementation of the project and the group of employers and consultants reached a single conclusion during a joint meeting and determined a value for each risk.

For risk assessment using Fuzzy FMEA, we have used FuzzyTech software 5.54 to calculate the fuzzy risk priority number (FRPN). The generated model has 3 inputs and one variable output, as shown in Figure 4.

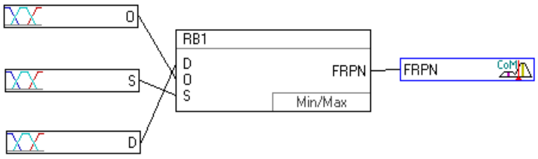
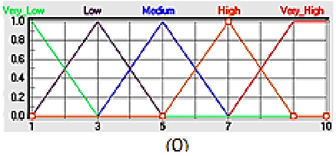


Figure 4 The Fuzzy Expert System for analyzing the critical mode of risk

The input variables include the occurrence, severity, and detection, each of which is presented in five levels with triangular membership functions (Figure 5).

A: Membership functions for the probability of occurrence

B: Membership functions for severity



C: Membership functions for detection/ control

Figure 5 The membership function of the O, S, D input variables

Identified risks and their prioritization using the Fuzzy FMEA method are shown in Table 7.

Table 7 Prioritization of identified risks based on the FRPN

category	Specified risk	O	S	D	FRPN
Technological	1.Inaccurate data transfer from basic design to detail design	5	9	5	520.2
	2.Changes in budget, schedule, and executive procedures	5	5	4	230.2
	3.Inaccuracy in controlling and matching the plan and execution	4	5	3	140.2
	4.Inaccurate insertion of technical and executive documents	3	4	2	50.50
	5.Lack of project planning and control processes and project delays' resulting from this factor	3	6	3	100
	6.The inappropriate selection of the execution method and the lack of up-to-date and appropriate standards for execution	3	4	3	50.50
	7.Lack of full mastery of the consultant on project conditions	6	8	6	622.54
	8.Lack of quality and delay in equipment supply	6	4	4	186.8
	9.Inadequate specifications of the project	5	4	4	186.8
	10.Changes in the design and scope of tasks	5	4	4	186.8
	11.Employer's low experience	5	7	5	590.1
	12.Management weakness of the project executive	8	8	4	520.27
	13.Rise of a commissioning problem due to unqualified execution of construction and installation	6	7	5	527.56
	14.Accidents for manpower and equipment	3	5	4	140.2
social	15.Popular strikes and protests	3	7	5	180.42
	16.Changes in laws and regulations	3	5	3	100
	17.Employer's interventions	4	7	5	350.32
	18.Inappropriate way of bidding and selecting contractors	5	7	5	520.2
	19.Administrative bureaucracy existing in the administrative agencies associated with the project	8	7	8	715.1
	20.Lack of specialized and skilful human resources	5	7	5	520.2
	21.Problems with the neighbors and residents of the region regarding construction	4	3	7	138.28
	22.Problems caused by robbery from the workshop	3	5	5	180.42
Economic	23.Failure to review the project contract specifications	3	5	3	100
	24.Shortage or lack of materials, machinery and equipment	4	6	2	186.8
	25.Inadequate estimation of the project implementation cost	6	5	3	180.42
	26.Low financial strength of the employer	7	8	7	715.1
	27.Failure to supply equipment due to political and economic sanctions	5	6	7	529.98
	28.Inappropriate way of contracting with executive agents	3	5	4	140.2
	29.Lack of human resource productivity	3	5	2	100
environmental	30.Power location and access roads	3	5	3	180.42
	31.Creation of noise pollution	5	6	3	230.2
	32.Creation of soil and climate pollution	2	4	3	50.50
	33.Inappropriate atmospheric conditions	5	5	5	280
	34. Supply of water and power to the workshop	3	5	9	180

It's important to note that in the Fuzzy FMEA, there is no base for the FRPN with which to compare the data and determine the critical levels. We used statistical methods in this research to determine the critical level.

Using the SPSS software and based on the distribution results, the FRPN values were obtained as 283.27 for 34 risks, and the standard deviation was obtained as 206.48. The critical limit for detected risks was considered the sum of the mean value with the standard deviation of FRPNs, which was equal to 489.75. Given the critical level obtained, we detected 10 risks as the critical risks using the Fuzzy FMEA method, as shown in Table 11 in an order of priority.

Table 8 Critical risks resulting from Fuzzy FMEA

Code	Critical risks	RPN
A_1	Low financial strength of the employer	715.1
A_2	Administrative bureaucracy existing in the administrative agencies associated with the project	715.1
A_3	Lack of full mastery of the consultant on project conditions	622.54
A_4	Employer's low experience	590.10
A_5	Failure to supply equipment due to political and economic sanctions	529.98
A_6	Rise of a commissioning problem due to unqualified execution of construction and installation	527.56
A_7	Management weakness of the project executive	520.27
A_8	Lack of specialized and skilful human resources	520.20
A_9	Inappropriate way of bidding and selecting contractors	520.20
A_{10}	Inaccurate data transfer from basic design to detail design	520.20

To analyze the impact of critical risks on the most effective project objectives (project schedule management, project cost management, project quality management and project procurement management), we used the Fuzzy TOPSIS Hierarchy Analysis Method.

The hierarchical analysis chart has been presented at three levels, as shown in Figure 6.

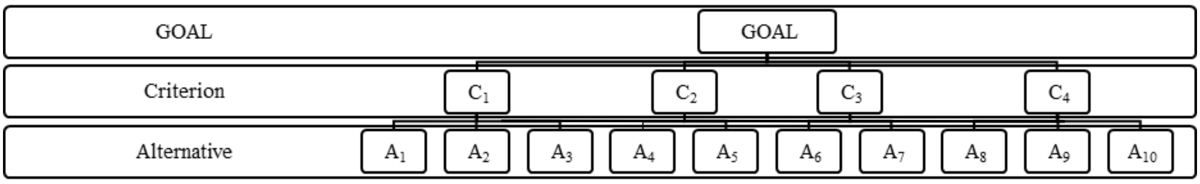


Figure 6 Analytical Hierarchy Chart

The formation of the hierarchy of the proposed model was followed by the assessment of the weights of the criteria and the ranking of alternatives by decision makers (including the contractor's representative, consultant, and employer) by use of the linguistic terms presented in tables 4 and 5, the results of which are shown in Tables 9 and Table 10.

Table 9 The importance weight of the criteria

Code	D1	D2	D3
C1	ML	M	ML
C2	ML	ML	ML
C3	VH	H	H
C4	H	VH	H

Table 10 The ratings of the three candidates by decision makers under all criteria

Alternative	Criteria	D_1	D_2	D_3		D_1	D_2	D_3		D_1	D_2	D_3		D_1	D_2	D_3
A1	C_1	VG	G	VG	C_2	VG	VG	VG	C_3	VG	VG	VG	C_4	VG	VG	VG
A2		VG	VG	VG		MG	F	MG		F	G	F		VG	G	VG
A3		G	G	VG		G	MG	G		VG	VG	VG		F	MG	MG
A4		G	MG	G		VG	VG	G		VG	VG	VG		VG	G	VG
A5		G	VG	VG		G	G	VG		VG	VG	VG		VG	VG	VG
A6		MG	F	F		MG	MG	G		VG	VG	VG		VG	VG	VG
A7		MG	MG	F		VG	G	G		MG	G	G		VG	G	G
A8		F	G	G		G	G	VG		VG	VG	VG		VG	VG	VG
A9		MG	MG	F		VG	MG	G		MG	G	F		VG	VG	VG
A10		MG	F	G		MG	MG	MG		VG	G	VG		F	F	F

Now the linguistic variables in Tables 9 and 10 are converted to triangular fuzzy numbers. After normalization based on Equation 9, the weighted normal matrix, which is the result of the fuzzy multiplication of the normal matrix by the weight of the criteria, is calculated (Table 11). Then the weighted fuzzy decision matrix was calculated by using 13 and 14 relationships of ideal positive and negative ideal numerical values. Finally, the relative proximity of each of the options to the ideal solution (relation 15) was determined and descended (Table 12).

Table 11 The fuzzy weighted normalized decision matrix

Code	C_1	C2	C_3	C_4
A_1	(0.14, 0.35, 0.57)	(0.09, 0.30, 0.50)	(0.69, 0.93, 1.00)	(0.69, 0.93, 1.00)
A_2	(0.15, 0.37, 0.57)	(0.04, 0.19, 0.42)	(0.33, 0.59, 0.80)	(0.64, 0.90, 1.00)
A_3	(0.13, 0.34, 0.57)	(0.06, 0.25, 0.48)	(0.69, 0.93, 1.00)	(0.43, 0.72, 0.90)
A_4	(0.11, 0.31, 0.55)	(0.08, 0.29, 0.50)	(0.69, 0.93, 1.00)	(0.64, 0.90, 1.00)
A_5	(0.14, 0.35, 0.57)	(0.08, 0.28, 0.50)	(0.69, 0.93, 1.00)	(0.69, 0.93, 1.00)
A_6	(0.06, 0.21, 0.43)	(0.06, 0.23, 0.47)	(0.69, 0.93, 1.00)	(0.69, 0.93, 1.00)
A_7	(0.07, 0.23, 0.47)	(0.08, 0.28, 0.50)	(0.49, 0.78, 0.97)	(0.59, 0.87, 1.00)
A_8	(0.09, 0.28, 0.51)	(0.08, 0.28, 0.50)	(0.69, 0.93, 1.00)	(0.69, 0.93, 1.00)
A_9	(0.07, 0.23, 0.47)	(0.07, 0.26, 0.48)	(0.38, 0.65, 0.87)	(0.69, 0.93, 1.00)
A_{10}	(0.08, 0.26, 0.49)	(0.05, 0.21, 0.45)	(0.64, 0.90, 1.00)	(0.23, 0.47, 0.70)

Table 12 The distance measurement,closeness coefficient and rank order of alternatives

Code	d^+	d^-	CC_i	Rank
A_1	0/90521	1/86049	0/67270	2
A_2	1/27170	1/52074	0/54459	9
A_3	1/12836	1/66751	0/59642	6
A_4	0/97459	1/80997	0/62425	4
A_5	0/91728	1/96579	0/68184	1
A_6	1/03245	1/71522	0/48907	5
A_7	1/19784	1/62527	0/65000	7
A_8	0/96187	1/80326	0/57570	3
A_9	1/2320	1/56000	0/65214	8
A_{10}	1/4286	1/36754	0/55872	10

The results of analysis of the experts' opinions using the proposed model for risk management in the construction of power plant projects showed that lack of equipment supply due to political and economic sanctions (0.681) is the most important risk based on the four examined criteria. The employer's low financial strength (0.672) and the shortage of specialized and skilful human resources (0.652) were ranked second and third respectively, and employer's low experience (0.650), the occurrence of a problem in commissioning due to unqualified implementation of construction and installation (0.624), the consultant's lack of full mastery on project conditions (0.596), weakness in workshop management (0.575), inappropriate method of bidding and contractor selection (0.558), the administrative bureaucracy available in administrative agencies related to the project (0.544) and the inaccurate data transfer from basic design to detail design (0.489) were ranked fourth to tenth respectively.

These results are consistent with the objective conditions and evidence of these projects. Political and economic sanctions have always had an impact on the economy and infrastructure, and their impact depend on the severity level of sanctions. Banking sanctions in general and the sanctions imposed on the Central Bank in particular disturbed the monetary exchanges in Iran and caused a lot of disruptions in its trade activities. The sanctions led to a significant reduction in the country's foreign exchange earnings, and led to a sharp and severe decline in the supply of foreign exchange in the market, resulting in a sharp increase in the exchange rate. The supply of foreign exchange needs of the country faced a plethora of problems due to the shortage of foreign exchange reserves. Therefore, the allocation of foreign currency to imports was prioritized, and even some commodities were subject to non-allocation of the government's currency, which was followed by a sudden increase in the price of many commodities. Many domestic products, especially in the private sector, faced reduced production due to their dependence on imports of intermediate goods and raw materials, and some firms were closed in some cases. Like other economic and infrastructure activities, power plant projects also faced problems due to their being technology-based and the need to import technology to the country, and also due to the employer's reduced power to supply the required resources and the existence of technological sanctions in this sector.

It should be noted that in the knowledge-based economy of the current era, intellectual property, especially human capital, is the most important asset of the organization, and the latent success of organizations is rooted in the ability and expertise of their workforce. Many of the tasks in projects are performed by the human resources of the employer, the contractor and the consultant. These forces play a key role in achievement of the predetermined goals of organizations. In addition, due to the complicated process of power plant construction and the lack of sufficient experience, there is a significant deviation in some stages of the project between the predicted volumes of work and the actual values, which in turn leads to repeated delays, increased project costs and reduced quality, thereby influencing other predetermined goals for the project. Therefore, we can increase the rate of success and achievement of project sustainable goals by implementing effective risk management in such projects. This is because it leads to greater mastery on the risks of projects and the adoption of appropriate decisions under different conditions of the project.

As mentioned, one of the most important steps in risk management is risk response. In the following, according to the case studies conducted in Mazandaran small-scale power plants, the following suggestions are presented in order to respond and face critical risks:

- Planning financing such as foreign financing, long-term loans, sale of participation bonds, etc.
- Preparing the cash flow of the project at the beginning of the construction phase and installing and obtaining the commitment of the shareholders and the board in committing to the payments
- Selection of intermediaries and the third factor to meet the required needs
- Supply from another source or change in part of the project due to lack of access to the required specific materials or technology
- Obligation to establish a knowledge management system, documentation and project events by the power plant project management to use the planning and management of future projects
- Planning the required resources based on the priorities of the project schedule for the optimal use of existing containers
- .Using experienced experts and specialized software for project management and planning

5. Conclusion

Today, the ambiguous and complex atmosphere of large projects has forced project managers to use modern management tools and modern knowledge of the world. The dynamism and complexity of the manufacturing industry is such that uncertainty and risk are their inherent characteristics. Conducting this research in order to achieve sustainable risk management in large power plant projects that can play a significant role in achieving these projects to predetermined goals (time, cost, etc.). One of the features of the present study was to present a hybrid model for identifying and evaluating sustainable risk in a fuzzy environment. Critical risks were first identified using the Fuzzy FMEA method. This technique is a traditional method of risk assessment and evaluates only three parameters of probability of occurrence, severity of effect and the amount of control. In order to investigate the effect of other criteria on the prioritization of critical project risks, the Fuzzy TOPSIS hierarchical analysis method has been used. The results observed in the proposed model for sustainable risk management of construction projects showed the use of verbal and linguistic expressions with the help of fuzzy theory to answer questionnaires and complete the pairwise comparison matrix to collect information from experts and decision makers, better results and It contains more real. Also, the results of the study showed that the impossibility of providing equipment due to political and economic sanctions is recognized as the most important risk of power plant construction according to the four criteria. After that, the risk of low financial capacity of the employer and lack of specialized and skilled human resources were also in the second and third ranks, which indicates the suitability of the proposed model with the conditions of ambiguity and uncertainty of the studied projects.

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