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Designing Human Health Risk Management Model for Dam Construction Projects

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Abstract

Identifying the risks of dam construction projects due to their high importance in terms of utilization, the amount of investment they invest in, the location of the region, the nature of the complexity of the project, and the presence of many uncertainties, including natural disasters and costs High builds are of special importance. Selection and implementation of the project with the least risk can lead to economic savings, optimal use of resources, increased productivity, flood control and supply of drinking water, agriculture and industry. Based on the results of this study, the "human factors" factor in the probability of occurrence and outcome in the category of severity of risk was the highest score among the indicators related to risk factors assessment of dam construction projects. In this research, first, identify the main risks of the project through a questionnaire and then identify the response strategies for the most critical risks, and finally, with the help of the decision model, prepare and, through paired comparisons, the best strategy for the most important human risk factors in the Polrood dam project is selected. In order to assess the risk in the dam, the risk parameters were identified and prioritized in different stages of the project, as well as 16 sub-subsets in four categories of risk factors: human, technical-environmental, environmental and psychological factors, and using the method DEMATEL-ANP were evaluated and ranked. "The lack of sufficient training to use devices and tools" was the most critical.

Keywords: Risk Management; ANP; Human Factors; Damping.

1. Introduction

One of the major areas in the project management standard is project risk management. The status of this topic, especially in the current context of projects that are at any moment in the face of the crisis, becomes more prominent. Project environment is affected by uncertainty and this situation is more acute for big projects. On the other hand, in the life cycle of the project, the establishment and monitoring of safety are important and necessary conditions for the start, completion, and operation of the project, despite the role Particularly this factor in project success, due to the influence of various factors such as cultural, social, economic and technical issues, does not make much interest in this category, especially in our country. The occurrence of various incidents and multiple financial and financial losses are the result of this neglect. Therefore, by implementing the risk management process and considering the impact and probability of occurrence of any of the events caused by the lack of attention to the safety category, it is possible to prevent the occurrence of events whose result is the waste of time, cost and even the quality of the project while improving the level

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of safety of the project. Most accidents happen under the influence of human factors Gives. These errors may be negligent (due to factors such as neglect and diversion, lack of adequate training or instructions, lack of ability and lack of motivation) or intentional (war, sabotage, etc.) [1]. Human factors as the main factor in project progress, as it can play an important role in project progression, can increase the risks and risks during the project on the other hand. These errors are exacerbated in major projects such as dam construction due to the advanced manufacturing industry, machinery, general project conditions, its location and other factors. Increasing the risk of large projects, in addition to compromising the lives and health of those involved, can have a legal impact on contractor companies and employers, and undermine their performance. In other words, the risk of any industrial project in terms of economic, cultural, social, etc. will reflect on the success of the project.

In order to determine the importance and necessity of safety at the workplace, it is necessary to identify the existing agents, then, after reviewing and classifying the various factors, an appropriate implementation procedure should be developed for the appropriate response in order to reduce the risk. In this research, with the aim of reducing the human health risk factors in the Polrood dam construction project, the factors related to human error including failure to observe safety tips (HSE), machinery, drilling, geographic location, climate, workload, Landslide, etc. The surveys and indicators associated with each of the factors will be ranked. Then, based on the significance and role of each of the factors in creating risk, an appropriate model for reducing errors and reducing risk The project will provide safety enhancements. So far, various studies have been carried out on risk assessment, and many models have been used in this area, but in most of them experts have not been familiar with the expertise of the experts in identifying and determining the weight and effectiveness of effective parameters on risk, in other words, the weight of the risk parameters is the same. It has been considered that in practice it seems to be faced with error. This issue is one of the most important aspects of the difference between the research and the present study. As a result of this study, we have determined the criteria and sub-criteria of influencing and influencing the severity of safety risks with the help and relying on experts' expertise in the project of the Polrood dam project. Has been. Using Delphi technique as a method for acquiring group knowledge that is a process with predictive structure and helping to make decisions through routing tracks, collecting information, and eventually group consensus, as well as combining DEMATEL-ANP techniques for decision making With the aim of discovering innovative and reliable ideas and providing relevant information for multi-dimensional decision making, it is possible to choose an effective strategy among multi-risk response strategies.

2. A Review of Previous Studies

Petrilo et al. investigated human error in critical infrastructure projects. The complexity of the systems causes negative impacts on human resource performance in critical cases. The purpose of this study is to provide a DEMATEL-ANP compilation model for human error probability analysis. The developed model is used to assess how to reduce the risk of accidents. In this study, a fossil power plant has been evaluated under critical conditions [2]. Ortiz et al. examined differences between DEMATEL-ANP and ANP in six different projects [3]. A case study has been selected in the health care industry. The basis of this multi-criteria decision is based on the interaction and feedback criteria. Zhou et al. explores the safety assessment of high-risk projects in hydroelectric projects the use of accident analysis, SEM and ANP [4]. Saif al-Islam and colleagues studied a fuzzy and combined approach to risk assessment in construction projects [5]. The results of the studies on various papers indicate that the risks are interdependent, so the ANP fuzzy analysis network will need to make long calculations. To overcome this, the FBBN or Fuzzy Networking Network has been used to assess risk. Zheng et al. in a study, estimated the safety risk in construction projects taking into account existing uncertainties. In this study, fuzzy logic and Monte Carlo method are used to estimate the risk in uncertainty conditions [6]. Kumar et al. in a study to classify and standardize the level of human error, states that, in addition to mechanization, technology and automation of machines, increasing safety in system operations is one of the key parameters for increasing its productivity [7]. Abdul Hamid and Ahmed in their study presented a method for estimating the risk of human factors, determining the interval between repair and shutdown machines [8]. Mandal et al. reviewed a human error and risk taking priority on cranes using the HTA, SHERPA and Fuzzy VIKOR methods [9]. Garcarneilles et al. examined the risks in development projects in Turkey [10]. Wang et al. in a study developed a general framework for human risk analysis in coal mines during a crisis in China. Mining in critical conditions creates a death and life line [11]. Sosa et al. in a study on risk management included safety and health in construction projects [12]. Norouzi et al. evaluated the human error risk in a study. The human factor involves systemic information about human personality and behaviour to enhance safety [13]. Dickon et al. in a study entitled "Risk Analysis of Human Factors in Marine Conditions", while arguing that marine environments are among the most difficult and most stressful environments in the workplace and the consequences of human error can be It is very intense to investigate the risk associated with human factors in these environments based on the consequences of past events. The results of previous studies and the history of risk design with the DEMATEL-ANP compilation model. The results of previous studies indicate that the DEMATEL-ANP method in damming projects has not been used to determine the risks associated with human health [14]. Zheng et al. and Garcarneilles et al. have studies in this regard, but the method used in this study is somewhat different and unique. Using the combination of Delphi and DEMATEL-ANP techniques as one of the decision-making techniques, with the aim of discovering innovative and reliable ideas and providing relevant information for multi-dimensional decision making, it is possible to choose an effective strategy among several Risk response strategy .The network analysis process is a mathematical theory that systematically deals with all kinds of dependencies and has been successfully applied in various fields.

3. Preliminaries

3.1. Risk

In the new era, with the advent of industry and technology acceleration, there are many concerns about the adverse consequences that threaten human life. The destructive effects of these developments, such as the events of Fisen (France), Mexico City, Piper alpha (UK) and Chernobyl (Russia), which have emerged as human disasters and environmental pollution in general, disturbing the ecosystem, have led to a deeper human reflection on the aftermath Disregard for risk management issues in industrial activities. Risk management in the definition that the ISO organization has described as coordinated activities to control the risks of the organization, and risk management organizations seek to create programs to reduce risk levels. Risk and risk analysis, which is the core of risk management, has a significant impact on risk management and mitigation after initiating risk studies and identifying potential damaging factors in order to more accurately analyse the hazardous events and examine the consequences of it[15]. A lot of research has been done on this subject, including a peasant study. The main objective of this study is to provide a new model for risk assessment in dam construction projects. Damage projects have multiple risks due to high costs and complex spatial conditions. Failure to properly manage risks leads to time lag and increases in costs. In the present study, with the advice of experts and using the PMBOK standard, 42 risk categories were identified in the four phases of the project. Another study by Josie et al. [16]. Has identified and evaluated the potential risks posed by the construction of the dam. To do this, after identifying the activities and the environment, the study area was carried out according to the severity of the effect, the probability of occurrence and possible consequences of its exposure to humans, the environment and equipment, identification and classification of risks in the form of Delphi methodology. Then, the risk factors were classified into natural, biophysical and human events. The method used in this research is the Analytical Hierarchy Process (AHP), which after creating the hierarchical structure of the risks arising from the dam, the matrices of paired comparisons with respect to the probability of occurrence of risk and severity of effect (main risk indicators), for each criterion and sub criteria were formed relative to each other. Also, in order to achieve the relative and final weights of each of these factors, the Expert Choice software was introduced by entering the preferences values.

3.2. Human Project Factors

Today, manpower is known as the most important source of development projects for its successful implementation, but unfortunately due to low human resource costs, it is paying little attention to other resources such as materials and machinery. With proper management of human resources, which depends on its proper planning and development, it is possible to improve the performance of construction projects. Unfortunately, the position of human resources management in weak and limited development projects is summarized, and only in administrative and operational matters. In other words, most senior executives often know things like attracting, controlling, attending and attending, and listing salaries and benefits as human resource management tasks, and they often find training as ineffective or time-consuming, and only In certain cases, such as safety and health, they agree with it [16].

3.3. Risk Assessment and the Health of Human Factors in the Project

According to the World Health Organization, an estimated 68 to 157 million people are diagnosed with occupational diseases annually, with about 30-40% of them suffering from chronic diseases, and about 10% of them suffer permanent disabilities, 20% of all cancers are caused by cancer. According to the International Labor Organization (ILO), accidents and illnesses linked to annual work send two million people to death, bringing about 250000$ million in economic losses, bringing about 5,000 people a day the world loses its life due to work-related accidents and illnesses [2]. Today, many companies and businesses are worth the specialist human resources and are trying to educate and train these forces. Therefore, the protection of these forces against incidents has become a crucial issue for companies. For this reason, safety and compliance with existing standards, as well as safety management in the HSE, have benefited from special utility desks. On the other hand, looking at the number of casualties and accidents caused by work in Iran, we will find that the growth of about 15 percent annually of these events calls for more attention to the issues of HSE management among the enterprises of the country. Failure to observe and enforce HSE in construction workshops, which is one of the sources of the incident in the country's industry, imposes billions of dollars annually on the economic and social fabric of the country, if it is, perhaps, at a much lower cost than that It can be avoided by preventing incidents that have a lot of hidden costs.

In safety considerations, as with other issues, it is first necessary to identify the factors that cause the risks, and then plan to moderate or eliminate them. Identifying hazardous risks and ranking them for projects is a key part of the risk assessment phase in the risk management process in the HSE sector, because after this we will be able to implement risk mitigating measures for that activity and Control it during planning to deal with risk situations. In order to identify the risks of each activity, it is first necessary to identify the nature of the activity and the risks involved in that activity, and then, considering the importance and impact of the incidents caused by these risks to the contractor and the objectives of the project, classify these risks in order to focus. It uses resources to analyze and reduce them [4].

4. Research Methodology

4.1. Network Analysis Model (ANP)

The process of network analysis was designed and introduced by Professor Thomas L, Saaty in 1996. ANP method is generalized mood of AHP method so that to determine the weights of criteria in analytical process in this method, pair comparisons technique is used. In the cases that lower levels are effective on higher levels or the components which are located in a level but they aren't independent from each other, AHP cannot be used anymore. ANP technique doesn't require hierarchical structure and as the result, it shows more complicated relationships among different levels of decision as network and considers the interactions and feedbacks among criteria and alternatives. ANP technique can consider all interactions and relationships among decision making levels which form a network structure with a comprehensive framework. The clusters introduce the levels of decision making and curves show the interactions among the levels of decision making. The direction of curves also shows the dependency. Following figure indicates the comparison of hierarchical analysis process and network analytical process.

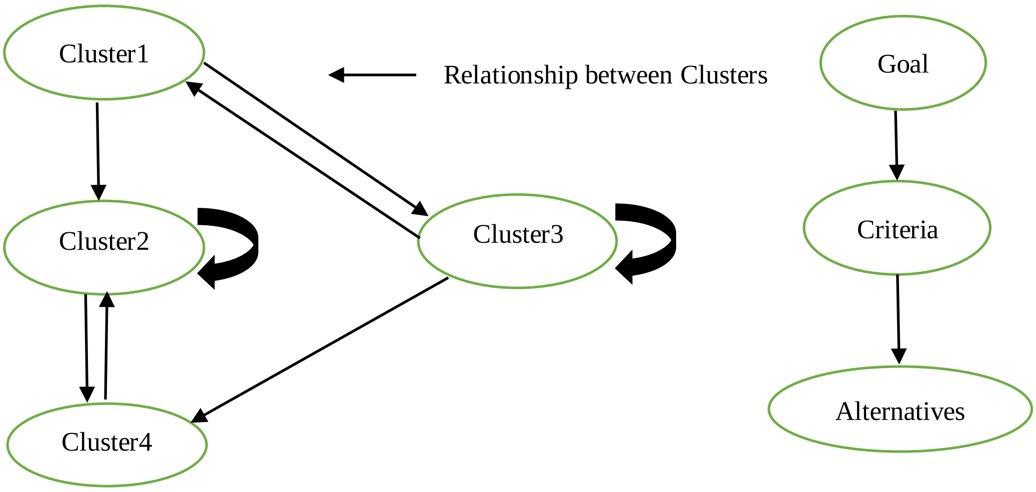

Figure 1. The process of hierarchical analysis and network analytical process

The process of network analysis includes four main levels which are:

1. Making model and structuring the problem.
2. Pair comparisons and priority vectors (decision components are compared in pairs in each part considering their importance in controlling the criterion and the parts are also compared in pairs considering their effect on the goal).
3. Formation of super matrix.
4. Choosing the best option.

After identifying relevant risks to the health of human factors in dam construction projects, final extraction of effective factors using elites' ideas, risks are modeled though questionnaire and then through prioritizing the factors through the model of network analysis process, the factors are ranked and collected data will be investigated and analyzed in Super Decision software. To determine the relationships between the criteria, DEMATEL technique is used. Using this technique, the pattern of internal relationships among criteria can be identified.

4.2. Fuzzy ANP

As it follows, the steps of performing fuzzy ANP will be mentioned separated by each phase.

First step: making model and structuring the problem: the aspects, criteria and items are specified and the relationship among them is expanded and the model and general structure of problem will be drawn as a network.

Second step: pair comparisons matrix

Third step: calculating weight vectors using development analysis method: to calculate weight vectors, fuzzy network analysis process is used which is based on development analysis method.

First step: expansion of fuzzy compound: to calculate the values of fuzzy compound expansion, the following equation is used.

$$\tilde{S}_i = \sum_{j=1}^{m} \tilde{M}_{g_i}^{j} \otimes [\sum_{i=1}^{m} \sum_{j=1}^{m} \tilde{M}_{g_i}^{j}]^{-1} \quad (1)$$

To calculate matrix, the following equations are used:

$$\sum_{j=1}^{m} \tilde{M}_{g_i}^{j} = (\sum_{j=1}^{m} I_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j) \quad (2)$$

Second step: calculating the degree of feasibility and preferences: after calculating $\widetilde{S_\iota}$ their great degree should be acquired towards each other. Generally, if $\widetilde{M_{10}}$ and $\widetilde{M_{20}}$ are two triangular fuzzy number, to calculate the degree of feasibility and preference of $\widetilde{M_2}$ towards $\widetilde{M_1}$ that is shown as $\widetilde{M_2} = (l_2, m_2, u_2) \geq \widetilde{M_1} = (l_1, m_1, u_1)$, the Equation number 3 is operationalized.

$$\text{V} (\tilde{M}_2 \geq \tilde{M}_1) Sup_{y \geq x} = [\min (u_{\tilde{m}\,2(x)}, u_{\tilde{m}\,1(x)})] \quad (3)$$

Equation 6 has been used to calculate the equation above.

$$\text{V} (\tilde{M}_2 \geq \tilde{M}_1) = \text{hgt} (\tilde{M}_2 \cap \tilde{M}_1) = u_{\tilde{m}\,2}(d) \quad (4)$$

Third step: to calculate the rate of a triangular fuzzy number bigness among k triangular fuzzy numbers, Equation 5 is used.

$$\text{V} (\tilde{M} \geq \tilde{M}_1 \tilde{M}_2 ... \tilde{M}_k) = \text{V} (\tilde{M} \geq \tilde{M}_1) \text{ and } (\tilde{M} \geq \tilde{M}_2) \text{ and } \ldots (\tilde{M} \geq \tilde{M}_k) \quad (5)$$

In the matrix of pair comparisons, to calculate the indicators, Equation 6 is used.

$$\text{d}' (A_i) = \text{,in V} (\tilde{S}_i \geq \tilde{S}_k) \text{, k=1,2,…,n; } k \neq i \quad (6)$$

Therefore, the weight indicators are shown using Equation 7.

$$W' = [d'(A_1), d'(A_2), ..., d'(A_n)]^T \quad (7)$$

Fourth step: descaling: in this step, weight vectors which are obtained from the previous steps are descaled.

$$\text{W}= [d(A_1), d(A_2), ..., d(A_n)]^T \quad (8)$$

Fourth level: formation of super matrix: super matrix is capable of limiting the coefficients for calculating all priorities and as the result cumulative effect of each component on other ones which are interacting with them. Super matrix includes the levels of target, aspects, decision criteria and options. In this matrix, the vector shows the effect of target on the aspects of decision and in another word, it shows the importance of aspects.

Fifth level: choosing the best option: in this level, obtained weights from DEMATEL techniques and development analysis will be inserted into unmatched super matrix (the one in which the weight of variables hasn't been considered) and then primary unmatched super matrix will turn to matched super matrix. After moderating the weights in matched super matrix, this super matrix will be empowered to the extent that matrix gets stable or so-called becomes converged and limited super matrix is formed. Finally, optimal options will be extracted from this super matrix.

4.3. Fuzzy DEMATEL Technique

Memorial Battle Institute invented the abovementioned technique in a research supervised by the core of Zeno research. Primary model of DEMATEL was used for achieving how to deal appropriately with disordering phenomena in the global scale. The superior advantage of this model in analyzing causal relationships between sets of variables. The used technique in this study is based on used method by Wu and Lee that its steps will be explained as follows [17].

First step: designing decision making matrix: to assess the relationship and effects among study criteria, matrix which includes the target and criteria is first designed in which the relationship between them is considered. In order for this, pair comparisons questionnaire has been designed. To assess the rate of effect of factors, a five-level criterion has been used.

Second step: calculating fuzzy matrix of direct relationships: after collecting the elites' ideas about the rate of factors' effectiveness on each other, direct relationships matrix (Z) which is a matrix of n multiplied n, is formed. Then mean matrix is calculated for collecting elites' ideas using Equation 9.

$$\tilde{Z} = (\frac{\tilde{z}^1 \otimes \tilde{z}^2 \otimes \ldots \otimes \tilde{z}^p}{p}) \tag{9}$$

The mean of each matrix, matrix Z which is called direct relationships fuzzy matrix, will be obtained. In this matrix, fuzzy numbers are triangular.

$$\tilde{z} = \begin{bmatrix} 0 & \tilde{z}_{12} \ldots\ldots \tilde{z}_{1n} \\ \tilde{z}_{21} & 0 \ldots\ldots \tilde{z}_{2n} \\ \ldots. & \ldots\ldots \quad \ldots\ldots \\ \tilde{z}_{n1} & \tilde{z}_{n2} \ldots\ldots 0 \end{bmatrix} \tag{10}$$

Third step: descaling fuzzy direct relationships matrix: in this step, descaled matrix of fuzzy direct relationships can be obtained based on Equations 13 and 14 from fuzzy direct relationships matrix.

$$\tilde{X} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} \ldots\ldots \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} \ldots\ldots \tilde{x}_{2n} \\ \ldots. & \ldots\ldots \quad \ldots\ldots \\ \tilde{x}_{n1} & \tilde{x}_{n2} \ldots\ldots \tilde{x}_{nn} \end{bmatrix} \tag{11}$$

$$\tilde{X}_{ij} = \frac{\tilde{z}_{ij}}{r} = (\frac{l_{ij}}{r}, \frac{m_{ij}}{r}, \frac{u_{ij}}{r}) \tag{12}$$

$$r = \max \left(\sum_{j=1}^{n} u_{ij} \right) \tag{13}$$

Fourth step: drawing causal chart: in this step, the sum of rows and columns of matrix is calculated. In case the sum of rows and columns are respectively called the matrixes of R and j, the most row sum R shows the order of criteria which have influence on the intensity of other components and the most column sum j shows the order of criteria which are influenced. Out of summing these two, matrix (R+j) which is called superiority matrix and out of their difference, matrix (R-j) which is named relationship matrix, is obtained.

Fifth step: defuzzification of general relationship matrixes: to do this, de-fuzzing method of CFCS which has been proposed by Opricovic and Tzeng in 2003 in order for defuzzifiying, was used. To do this, the matrix which consists of triangular fuzzy numbers have been de-fuzzed using Equation 19 and the matrix will be obtained with definite final relationships.

$$L = \min (l_k); \; R = \max (u_k); \; k = 1, 2\ldots n \tag{14}$$

$$\Delta = R - L$$

Sixth step: calculating internal relationship matrix: based on the results of general relationships matrix and causal chart, internal relationships matrix will be calculated. Through descaling the column of general relationships matrix using linear soft, internal relationships matrix will be obtained. The weights of these tables are directly used in unmatched super matrix ANP.

4.4. Questionnaire

In order to design the model of determining relevant risks to the health of human factors in dam construction projects in several levels, questionnaires for the elites of the subject are required to be used. In the first step, in order to identify main aspects of relevant risks to the health of human factors in dam construction projects, questionnaires of elites are used. The elites in this step are asked to specify main aspects of relevant risks to the health of human factors in dam construction projects. After identifying main criteria, the sub-criteria that are the components of each one of criteria will be also specified using the ideas of elites. After determining the aspects and components of relevant risks with the health of human factors, some very important points need to be specified.

1. Determining the relationships and correlation among the aspects of risks.
2. Determining the relationships and correlation among sub-criteria.
3. Determining the importance of each one of main aspects.
4. Determining the importance of sub-criteria.

To achieve the cases above, combined technique of fuzzy DEMATEL-ANP is used in which the elites should be surveyed. After determining the aspects, sub-criteria, dependency among them as well as the priority and importance of each one, some solutions are required to be proposed in order to reduce and manage the risks. Due to this, holding a session with the elites of the company and Delphi technique, the solutions will be gathered and the appropriate ones are chosen. Due to pair comparisons questionnaire, a questionnaire is sent for elites and they are asked to conduct pair comparisons among the factors. Each one of questions in questionnaire above have been designed as 9 options and based on Likert scale. In this scale, the responses are separated into 9 groups. From the equal importance to absolute importance. The data and preferences can be seen in Table 1.

Table 1. The table of Likert scale

Fuzzy number	Verbal expressions	Code
(1, 1, 1)	Equal preference	1
(1, 1.5, 1.5)	Average or lower prefference	2
(1, 2, 2)	Average preference	3
(3, 3.5, 4)	Average to high preference	4
(3, 4, 4.5)	High preference	5
(3, 4.5, 5)	High to very high preference	6
(5, 5.5, 6)	Very high preference	7
(5, 6, 7)	Very high to absolutely high preference	8
(5, 7, 9)	Absolutey high preference	9

4.5. Statistical Population and Research Territory

Statistical population of current study are elites and managers in Khatamolanbia construction site. The elites above have the following conditions:

- The experience of at least 5 years in the field of construction projects
- Having at least Master degree
- Having defined organizational position in the organization

Place territory of the research is Gilan Province located in Islamic Republic of Iran. Time territory of the research is first half of 2016. Subject territory of the research is about human resource health and relevant issues to it.

5. Case study

The construction site of reservoir dam of Polrood in the north of Iran has been located in eastern part of Gilan province on the Polrood river, in the zone of Rudsar town and 18 kilometers from western south of coast city Kelachay and 5 kilometers of Rahim Abad town in geographical length of eastern 6, 17 and 50 and geographical width of northern 48, 58 and 36. The plan of reservoir dam of Polrood is one of big plans of water supply in Gilan that its identification and primary studies started from 1977 and its complementary studies lasted from 1983 to 2005. Finally, in 2007, the approval of specialized committee of the Energy Ministry was taken by Gilan Regional Water Company and it became supposed to a dam is constructed with reservoir volume of 132 million cubic meter and leading power of annually 210 million cubic meter 7 kilometers far from Rahim Abad of Rudsar town. The contract of this project executive operations was signed with Khatamolanbia site in Public bidding which was held in 2009 and dam project started from April 8th 2010 with the supervision of Qods Mahab Company.

Figure 2. A view of Polrood dam

5.1. Identifying the Aspects of Relevant Risks to the Health of Human Factors

In this step, through questionnaire and getting the ideas of elites in this issue, the aspects of relevant risks to the health of human factors were identified in the project of Rahim Abad Polrood dam in Gilan. In this step, taking advantage of Delphi technique and through doing 3 rounds of questionnaire in the form of an intensive session of several hours, finally, the elites reached an agreement on the aspects relevant risks to the health of human factors. According to elites, relevant risks to the health of human factors include following cases:

1. The accidents caused by human errors.
2. The accidents caused by devices' deficiency.
3. Effective spiritual factors on the workers' mind.
4. Environmental factors

5.2. Determining Sub-Factors of Relevant Risks to the Health of Human

In order to determine the rate of reliability of each one of sub-factors for entering into model, the elites were asked to give their ideas about the importance rate of each one of sub-factors for inserting into model and give 1 to the sub-factors which are qualified enough to be inserted into model and 0 to the ones which aren't reliable enough to be inserted into model. In order to consider an indicator for inserting the sub-factors into the final model, Lawshe equation is used so that considering the conducted calculations, the sub-factors that their CVR is at least 0.62, are qualified to be inserted into model. Validating effective sub-factor on the human resource health has been accomplished using the references that are extracted from the literature of the study.

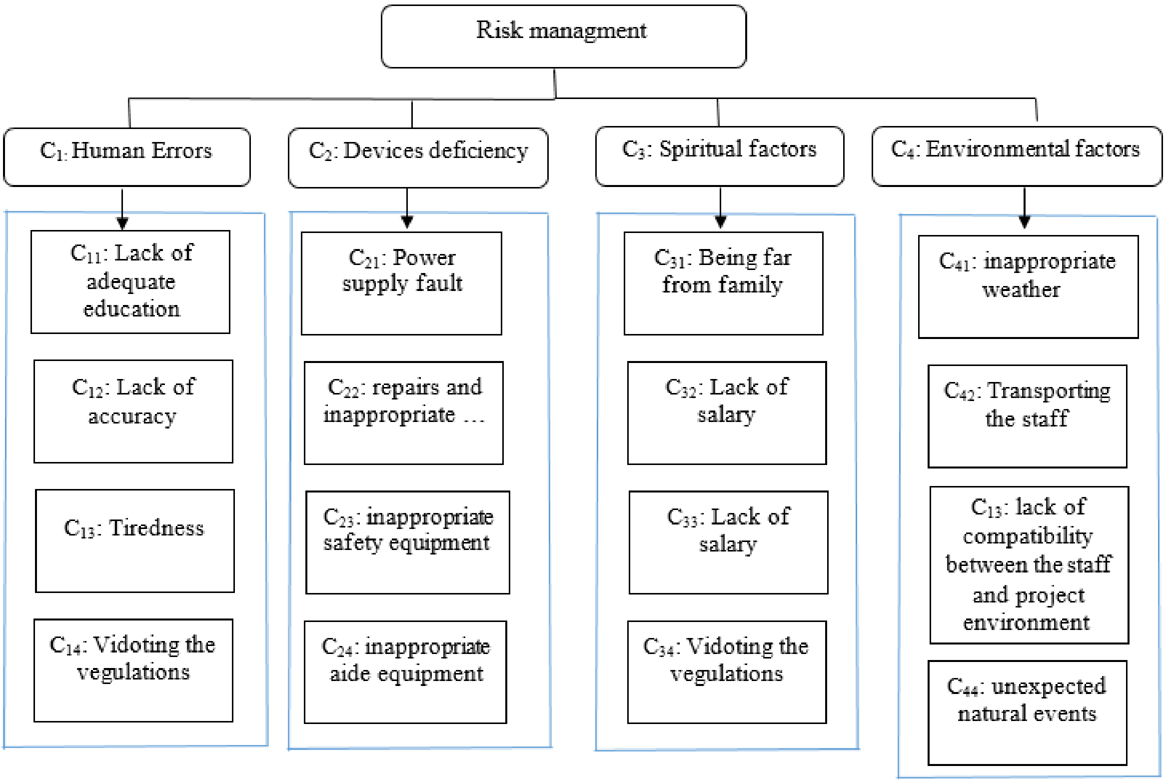

Figure 3. The factors and sub-factors of health risks of human resource in the case study

5.3. Determining the Relationships and Correlation among the Main Aspects

After identifying the aspects and components in previous section, to manage risks in this level, correlation and causal relationship among the aspects and also sub-criteria are identified so in this level through fuzzy DEMATEL technique, the causal relationships among the aspects and components will be determined whose levels will be mentioned as follows. To investigate the criteria, the ideas of 10 elites have been used. Fuzzy numbers in these matrixes are triangular and $\tilde{x}_{ij}$ is considered as fuzzy number (0, 0, 0). To consider the ideas of all elites, they will be taken arithmetic mean according to Equation 20.

$$\tilde{Z} = \left(\frac{\tilde{z}^1 \otimes \tilde{z}^2 \otimes \ldots \otimes \tilde{z}^p}{p}\right) \tag{15}$$

$\tilde{z}_{ij} = (\tilde{l}_{ij}, \tilde{m}_{ij}, \tilde{u}_{ij})$ In this equation, p is the number of elites and $\tilde{x}^1$, $\tilde{x}^2$, $\tilde{x}^3$ are respectively the matrix of pair comparisons of elite 1, elite 2 and elite P and $\tilde{z}$ is the triangular fuzzy number $\tilde{z}_{ij} = (\tilde{l}_{ij}, \tilde{m}_{ij}, \tilde{u}_{ij})$ .Fuzzy mean of elites' ideas about the effect of 4 factors have been shown in Table 2.

Table 2. Mean of all elites' ideas about the effect of main factors

Criterion	C_1Accidents caused by human errors	C_2 Accidents caused by devices deficiency	C_3 Spiritual factors affecting staff health	C_4 Environmental factors affecting staff health
C_1	(0.0000, 0.0000, 0.0000)	(2.5000, 3.5000, 4.5000)	(3.0000, 4.0000, 5.0000)	(5.5000, 6.5000, 7.2500)
C_2	(2.2500, 3.0000, 3.7500)	(0.0000, 0.0000, 0.0000)	(3.2500, 4.0000, 4.7500)	(6.5000, 7.5000, 8.0000)
C_3	(2.7500, 3.5000, 4.2500)	(6.5000, 7.5000, 8.2500)	(0.0000, 0.0000, 0.0000)	(7.5000, 8.5000, 8.7500)
C_4	(3.5000, 4.5000, 5.5000)	(3.5000, 4.5000, 5.5000)	(4.5000, 5.5000, 6.5000)	(0.0000, 0.0000, 0.0000)

To normalize obtained matrix, Equations 16 and 17 are used.

$$\tilde{H}_{ij} = \frac{\tilde{z}_{ij}}{r} = (\frac{l'_{ij}}{r}, \frac{m'_{ij}}{r}, \frac{u'_{ij}}{r}) \tag{16}$$

That r is obtained from the following equation:

$$r = \max_{1 \le i \le n} (\sum_{j=1}^{n} u_{ij}) \tag{17}$$

After calculating normalized matrixes, the matrix of fuzzy total relationships will be obtained considering Equations 18 to 21.

$$T = \lim_{k \to \infty} (\tilde{H}^1 \otimes \tilde{H}^2 \otimes \ldots \tilde{H}^k) \tag{18}$$

That in each entries of that, fuzzy number is as $\tilde{t}_{ij} = (l^t{}_{ij}, m^t{}_{ij}, u^t{}_{ij})$ and calculated as below:

$$[l^t{}_{ij}] = H_1 \times (I - H_1)^{-1} \tag{19}$$

$$[m^t{}_{ij}] = H_m \times (I - H_m)^{-1} \tag{20}$$

$$[u^t{}_{ij}] = H_u \times (I - H_u)^{-1} \tag{21}$$

In these equations, I is the matrix of one and H_1, H_m and H_u are each one matrix of $n \times n$ whose entries respectively form low, middle and high number of triangular fuzzy numbers of matrix H. Table 3 shows matrix t.

Table 3. The matrix of main criteria relationships

Criterion	C_1 Accidents caused by human errors	C_2 Accidents caused by devices deficiency	C_3 Spiritual factors affecting staff health	C_4 Environmental factors affecting staff health
C_1	(0.0419, 0.0952, 0.2329)	(0.0602, 0.1215, 0.2699)	(0.0678, 0.1337, 0.2932)	(0.0870, 0.1539, 0.3086)
C_2	(0.0651, 0.1335, 0.3014)	(0.0511, 0.1159, 0.2835)	(0.0789, 0.1543, 0.3401)	(0.1026, 0.1805, 0.3607)
C_3	(0.0616, 0.1213, 0.2680)	(0.0884, 0.1510, 0.3019)	(0.0490, 0.1100, 0.2676)	(0.1024, 0.1707, 0.3264)
C_4	(0.0689, 0.1351, 0.2991)	(0.0706, 0.1383, 0.3070)	(0.0819, 0.1547, 0.3361)	(0.0539, 0.1213, 0.2928)

Next step is obtaining the sum of rows and columns of matrix T. the sum of rows and columns are obtained considering Equations 22 and 23.

$$\tilde{D} = (\tilde{D}_i)_{n \times 1} = [\sum_{j=1}^{n} \tilde{T}_{ij}]_{n \times 1} \tag{22}$$

$$\tilde{R} = (\tilde{R}_i)_{1 \times n} = [\sum_{j=1}^{n} \tilde{T}_{ij}]_{1 \times n} \tag{23}$$

That $\tilde{D}$ and $\tilde{R}$ are respectively the matrix of $n \times 1$ and $1 \times n$.The rate of indicators' importance ($\tilde{D}_i + \tilde{R}_i$) and the relationship among criteria ($\tilde{D}_i - \tilde{R}_i$) are determined. If $\tilde{D}_i - \tilde{R}_i > 0$, the relevant criterion is effective and if $\tilde{D}_i - \tilde{R}_i < 0$, the relevant criterion is affected. Table 4 shows $\tilde{D}_i + \tilde{R}_i$ and $\tilde{D}_i - \tilde{R}_i$.

Table 4. The importance and effectiveness of main criteria (fuzzy numbers)

$\tilde{D}_i - \tilde{R}_i$	$\tilde{D}_i + \tilde{R}_i$	Criterion
(-4.9633, 0.0349, 4.974`8)	(3.2758, 6.1739, 13.2140)	C_1
(-4.8445, 0.5315, 6.1373)	(3.6384, 6.8414, 14.6202)	C_2
(-5.6680,-0.2440,4.9552)	(3.5532, 6.6456, 14.1764)	C_3
(-5.6110, -0.1447, 5.4870)	(3.7207, 6.9738, 14.8188)	C_4

In next step, fuzzy numbers $\tilde{D}_i + \tilde{R}_i$ and $\tilde{D}_i - \tilde{R}_i$ obtained from previous step are de-fuzzed according to Equation 24.

$$B = \frac{(a_1 + a_3 + 2a_2)}{4} \tag{24}$$

De-fuzzed B is number $\tilde{A} = (a_1, a_2, a_3)$. Table 4 shows de-fuzzed numbers of Table 5.

Table 5. The importance and effectiveness of criteria (definite numbers)

$(\tilde{D}_i - \tilde{R}_i)^{def}$	$(\tilde{D}_i + \tilde{R}_i)^{def}$	Criterion
0.0203	7.2094	C_1
0.5889	7.9854	C_2
-0.3002	7.7552	C_3
-0.1034	8.1218	C_4

Figure 4 also shows the rate of importance and effectiveness among the criteria. Horizontal axis of chart shows the importance of criteria and vertical one is about the effectiveness or affectability of criteria.

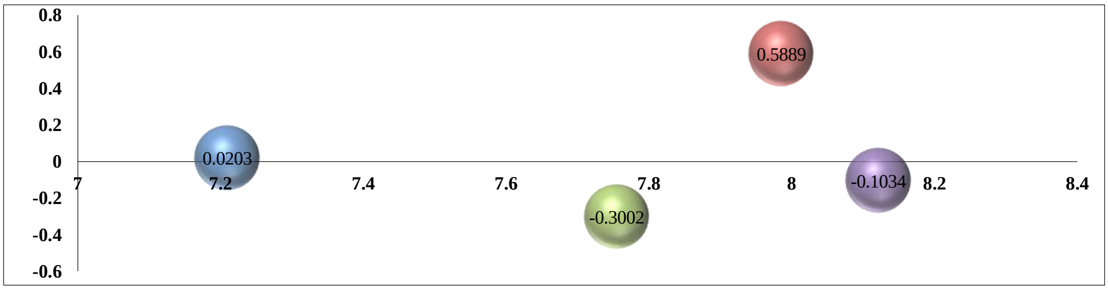

Figure 4. Causal chart f main criteria

As it is seen, the criterion of environmental factors has more length of source than other criteria, this is because this criterion is more important than others in the flow of effectiveness and affectability. In the same way, we determine the causal relationships of the underlying criteria of the factors using the fuzzy DEMATEL technique.

5.4. The Steps of Obtaining the Weight of Components with Fuzzy Network Analysis

Based on super-matrix, the levels of calculating components' weights are:

First step: to collect the elites' ideas, respondents' pair comparisons were taken geometric mean.

Second step: calculating eigenvector: to calculate eigenvector of each one of cumulated pair comparisons tables, logarithmic method of least squares is used so that Equation 25:

$$w_k^s = \frac{\left(\prod_{j=1}^{n} a_{kj}^s\right)^{1/n}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{ij}^m\right)^{1/n}}, \quad s \in \{l, m, u\} \tag{25}$$

In which: $\tilde{w}_k = (w_k^l, w_k^m, w_k^u) \quad k = 1,2,3,\dots,n$

Third step: formation of eigenvectors (W_{ij}). These matrixes include eigenvectors which have been obtained from pair comparisons of second step.

It has to be noticed that if in intra surface eigenvectors matrix, one or some entries aren't seen in main diameter (1, 1, 1) the reason is that normalization has been conducted in that column. Normalization is so that all fuzzy numbers of that column are divided into the sum of middle values of fuzzy numbers of that column. Table 6 and 7 show the matrixes of eigenvector.

Table 6. The matrix of eigenvector (weight) of criteria levels towards goal level

Factors	Eigenvector
C_1	(0.136, 0.146, 0.179)
C_2	(0.235, 0.293, 0.323)
C_3	(0.173, 0.183, 0.232)
C_4	(0.301, 0.377, 0.397)

Table 7.super Matrix of eigenvector (weight) of sub-criteria level towards criteria level

	C_1 Accidents caused by human errors	C_2 Accidents caused by devices deficiency	C_3 Spiritual factors affecting staff health	C_4 Environmental factors
C_{11}	(0.134, 0.148, 0.188)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)
C_{12}	(0.163, 0.192, 0.22)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)
C_{13}	(0.185, 0.236, 0.261)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)
C_{14}	(0.196, 0.227, 0.262)	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)
C_{21}	(0, 0, 0)	(0.122, 0.131, 0.17)	(0, 0, 0)	(0, 0, 0)
C_{22}	(0, 0, 0)	(0.155, 0.172, 0.21)	(0, 0, 0)	(0, 0, 0)
C_{23}	(0, 0, 0)	(0.189, 0.227, 0.252)	(0, 0, 0)	(0, 0, 0)
C_{24}	(0, 0, 0)	(0.175, 0.207, 0.235)	(0, 0, 0)	(0, 0, 0)
C_{31}	(0, 0, 0)	(0, 0, 0)	(0.138, 0.147, 0.176)	(0, 0, 0)
C_{32}	(0, 0, 0)	(0, 0, 0)	(0.145, 0.159, 0.187)	(0, 0, 0)
C_{33}	(0, 0, 0)	(0, 0, 0)	(0.168, 0.2, 0.226)	(0, 0, 0)
C_{34}	(0, 0, 0)	(0, 0, 0)	(0.196, 0.239, 0.266)	(0, 0, 0)
C_{41}	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0.137, 0.159, 0.189)
C_{42}	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0.123, 0.128, 0.17)
C_{43}	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0.163, 0.199, 0.228)
C_{44}	(0, 0, 0)	(0, 0, 0)	(0, 0, 0)	(0.223, 0.285, 0.306)

5.5. Obtaining Eigenvector of Main Factors towards the Goal and Sub-Factors towards Main ones Using Fuzzy ANP

In this step, obtained eigenvectors of fuzzy ANP are multiplied in the matrix of total relationships of fuzzy DEMATEL. To multiply these two matrixes, main factors total relationships matrix obtained from fuzzy DEMATEL is first normalized. Table 8 shows normalized matrix of total relationships of main factors have been shown.

Table 8. Matrix of total relationships of main factors

	C_1	C_2	C_3	C_4
C_1	(0.0000, 0.0000, 0.0000)	(2.5000, 3.5000, 4.5000)	(3.0000, 4.0000, 5.0000)	(5.5000, 6.5000, 7.2500)
C_2	(2.2500, 3.0000, 3.7500)	(0.0000, 0.0000, 0.0000)	(3.2500, 4.0000, 4.7500)	(6.5000, 7.5000, 8.0000)
C_3	(2.7500, 3.5000, 4.2500)	(6.5000, 7.5000, 8.2500)	(0.0000, 0.0000, 0.0000)	(7.5000, 8.5000, 8.7500)
C_4	(3.5000, 4.5000, 5.5000)	(3.5000, 4.5000, 5.5000)	(4.5000, 5.5000, 6.5000)	(0.0000, 0.0000, 0.0000)

After multiplying the matrix above in Table 6, Table 9 will be obtained which shows final weight of main factors affecting staffs' heath in dam construction project of Rahim Abad Polrood.

Table 9. Final weight of main factors towards the goal

Total relationships matrix	Fuzzy weight	Definite weight
C_1	(0.1293, 0.3325, 0.7592)	0.3662
C_2	(0.1775, 0.4348, 0.9184)	0.4001
C_3	(0.0643, 0.1164, 0.3098)	0.1535
C_4	(0.0643, 0.1164, 0.3098)	0.1535

To determine final weight of sub-criteria, sub-criteria's normalized total relationships matrix should be first obtained. To determine final weight of indicators towards goal, their weight (eigenvector) (Table 7) should be first multiplied in the matrix of sub-criteria's normalized total relationships and obtained result should be multiplied in final weight of factors towards goal (Table 9). The obtained results of these operations have been shown in Table 10.

Table 10. Final weight of sub-criteria towards the goal

Indicators	Fuzzy weight	Definite weight	Rating
C_{11}	(0.181, 0.203, 0.233)	0.195	1
C_{12}	(0.048, 0.069, 0.096)	0.07	7
C_{13}	(0.039, 0.049, 0.097)	0.06	9
C_{14}	(0.066, 0.101, 0.131)	0.1	3
C_{21}	(0.065, 0.096, 0.126)	0.096	4
C_{22}	(0.063, 0.077, 0.128)	0.086	5
C_{23}	(0.069, 0.108, 0.136)	0.106	2
C_{24}	(0.036, 0.049, 0.074)	0.051	14
C_{31}	(0.035, 0.060, 0.064)	0.056	10
C_{32}	(0.04, 0.054, 0.081)	0.055	12
C_{33}	(0.062, 0.091, 0.123)	0.081	6
C_{34}	(0.025, 0.035, 0.074)	0.043	15
C_{41}	(0.003, 0.004, 0.031)	0.009	16
C_{42}	(0.038, 0.059, 0.096)	0.062	8
C_{43}	(0.022, 0.069, 0.097)	0.052	13
C_{44}	(0.04, 0.07, 0.081)	0.056	11

6. Conclusion

As it was previously discussed, the goal of this study was designing a model for determining relevant risks to the health of human factors in dam construction projects. The first step which was taken due to this was a comprehensive cognition of problem using available resources so a comprehensive library study from the books, papers and theses related to this field was conducted and the principles of the study were accurately investigated to be profoundly familiar with the principles of the study. After relative familiarity with the concepts of issue, a comprehensive literature of the subject and relevant studies was reviewed and proposed. Used models in the subject literature were completely investigated to be able to be the basis for the study. In order to this, through conducted studies and identifying weaknesses and strengths of studies, it was tried to use positive points of studies and take some measures for filling the gaps of research. Firstly, relevant risks to the health of human resource in dam construction projects were identified in 4 main criteria which are as follows:

1. The accidents caused by human errors.
2. The accidents caused by the deficiency of devices.
3. Effective spiritual factors on workers' mind.
4. Environmental factors.

Then, some sub-criteria were determined for each one of these criteria. After identifying criteria, sub-criteria, using combined fuzzy DEMATEL-ANP method, each one of these criteria and their sub-criteria were ranked. Finally, in order to manage existing risks in these projects, some solutions were proposed using those risks can be managed. 5 variables which have higher effect on threatening the health of human resource in the project of Polrood dam in Rahim Abad Gilan are:

C_{11}: Lack of adequate training for use of devices and systems.

C_{23}: Accidents caused by inappropriate safety equipment.

C_{14}: The error caused by violating security regulations in workplace.

C_{21}: The accidents caused by the fault of power system.

C_{22}: The accidents caused by inappropriate repairs and maintenance of systems.

In order to propose some solutions for reducing the risks of human resources health in the project of Polrood dam in Rahim Abad Gilan, consulting the elites in this field, the following solutions were ultimately proposed to reduce and manage the risks above:

1. Proposing applied and suitable trainings in order to use the devices properly.
2. Supplying and proposing proper safety equipment for the staff.
3. Developing and modifying work security regulations in workshop environment by contractor.
4. Accurate supervision on meeting security regulations.
5. Repairing and inspecting power systems accurately and regularly.
6. Developing and performing regular program for monitoring appropriate performance of power system. Designing and strengthening HSE in the structure of project.

7. References

[1] Faisal I. Khan. Paul R. Amyotte., Dean G. DiMattia. "A new tool for human error probability calculation for offshore operation." Safety Science (April 2006): 313-334. doi.org/10.1016/S0925-7535 (06)00019-1.

[2] Antonella Petrillo, Francesco Longo, Agostino Bruzzone, Fabio De Felice. "Factors affecting the human error: Representations of mental models for emergency management" International Journal of Simulation and Process Modelling (January 2017): 12(3/4):287. DOI:10.1504/IJSPM.2017.10006511.

[3] Miguel A Ortíz, Heriberto A Felizzola, Santiago Nieto Isaza. "A contrast between DEMATEL ANP and ANP methods for six sigma project selection: a case study in healthcare industry." BMC Medical Informatics and Decision Making (September 2015). (Suppl 3):S3. doi.org/10.1186/1472-6947-15-S3-S3.

[4] Jian-Lan Zhou, Bai Zhe-Hua and Zhi-Yu Sun. "Safety Assessment of High-Risk Operations in Hydroelectric-Project Based on Accidents Analysis, SEM, and ANP." Hindawi Publishing Corporation Mathematical Problems in Engineering (October 2013): 163-172. dx.doi.org/10.1155/2013/530198.

[5] Muhammad Saiful Islama, Madhav Prasad Nepala, Martin Skitmorea, Meghdad Attarzadeh. "Current research trends and application areas of fuzzy and hybrid methods to the risk assessment of construction projects." Advanced Engineering Informatics (August 2017):112–131.doi. 10.1016/j.aei.2017.06.001.

[6] Limao Zhang, Yanhua Huang, Xianguo Wu, Miroslaw J. Skibniewski. "Risk-based estimate for operational safety in complex projects under uncertainty" Applied Soft Computing (May 2017):108–120. doi.org/10.1016/j.asoc.2017.01.020.

[7] Pramod Kumar, Suprakash Gupta, Mudit Agarwal. "Umesh Categorization and standardization of accidental risk-criticality levels of human error to develop risk and safety management policy." Safety Science (June 2016): 88-98. doi.org/10.1016/j.ssci.2016.01.007.

[8] Abdul Hameed, Faisal Khan, Salim Ahmed. "A risk-based shutdown inspection and maintenance interval estimation considering human error." Process Safety and Environmental Protection. (March 2016): doi.10.1016/j.psep.2015.11.011.

[9] Saptarshi Mandal, Karmveer Singh, R.K. Behera, S.K. Sahu, J. Maiti. "Human error identification and risk prioritization in overhead crane operations using HTA, SHERPA and fuzzy VIKOR method." Expert Systems with Applications (November 2015):7195-7206.doi. 10.1016/j.eswa.2015.05.033.

[10] G.E. Gürcanlıa, S. Baradanb, M. Uzuna. "Risk perception of construction equipment operators on construction sites of Turkey." International Journal of Industrial Ergonomics (March 2015):59–68.doi.10.1016/j.ergon.2014.12.004.

[11] Lijing Wang, Yanlong Wang, Qiyan Cao, Xiaodong Li, Jinquan Li, Xinwen Wu. "A framework for human error risk analysis of coal mine emergency evacuation in China." Journal of Loss Prevention in the Process Industries (July 2014):113–123. doi.org/10.1016/j.jlp.2014.05.007.

[12] Vitor Sousa, Nuno M. Almeida, Luís A. Dias. "Risk-based management of occupational safety and health in the construction industry – Part 1: Background knowledge." Safety Science (July 2014): 75–86. doi.org/10.1016/j.ssci.2014.02.008.

[13] Alireza Noroozi, Nima Khakzad, Faisal Khan, Scott MacKinnon, and Rouzbeh Abbassi"The role of human error in risk analysis: Application to pre- and post-maintenance procedures of process facilities." Reliability Engineering & System Safety (November 2013): 251-258.doi: 10.1016/j.ress.2013.06.038.

[14] Deacon T, Amyotte PR, Khan FI. "Human error risk analysis in offshore emergencies." Safety science. (July 2010):803-818. doi.org/10.1016/j.ssci.2010.02.013.

[15] Esfahani Seyed Hasan. "Risk assessment using the Risk Introductory Checklist" exploration and production magazine. (October 2009): No 87. 14-20.

[16] Josie Seyed Ali., Hoseini Seyed Mohsen., Tabib Shoushtari Mehrnoush. "Environmental risk assessment of Balarood Dam in Khuzestan in the making stage by using the Analytical Hierarchy Process (AHP)." marine science and technology research. (Spring 2010):Vol. 5, No. 1, 71-88 doi.org/10.1080/10807039.2013.821905

[17] Wei-Wen Wu, Yu-Ting Lee. "Developing global managers' competencies using the fuzzy DEMATEL method." Expert Systems with Applications (February 2007): 499-507. doi.org/10.1016/j.eswa.2005.12.005.