Prioritization of the risks associated with cost, quality and contracting in the implementation phase of construction projects using Analytic Hierarchy Process (AHP)

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Abstract

The success of a project is measured by the results that should be achieved based on the project's goals in terms of time, cost, and quality. In addition, the desired project results achievement depends on how the project risks are handled. Many companies start a project with only a vague view of the project's goals and priorities. Therefore, in this study, the risks associated with cost, quality and contracting in the implementation phase were prioritized in construction projects using hierarchical analysis method. The statistical population of this study composed of experts and managers of contracting companies (in Bojnourd cty). The present study was conducted based on an Analytic Hierarchy Process (AHP). Upon calculations, it was observed that according to the main weight obtained in project implementation phase, the components project cost risks, operational risks, risks of providing timely facilities, project-scheduling risks, human resources-specific risks and quality risks respectively have the highest and the lowest importance in this group. The calculations resulted from the main weight also indicated the following components respectively with the highest and lowest importance in project cost group: budget shortages, inability to settle the receivables of partial contractors, delay in payment of contractor's invoice cost, increased overhead costs due to delay in notification of drawings, contractor's increased overhead costs due to delay of employer in importing materials and poor wage and salary systems. The main weight resulted calculations also showed the following components with the highest and lowest importance in the quality group, respectively: poor quality of work performed by the contractor, poor tests in concrete's compressive strength test and low quality of studies.

Keywords: Risk management, hierarchical analysis, project management, project quality, project cost

Introduction

Risk management has been defined as follows: "a systematic planning process to identify, analyze, respond, and monitor the project risks". Such a management includes processes, tools, and techniques that help the project manager maximize the likelihood of positive events results and minimize that of harmful events results. Using the full risk management process, it can be argued that it is the project manager person who oversees the uncertainty of the project, and the conditions and events must not engage the management. Risk management, in any project of any kind, needs to be implemented and thus, reducing the possible losses as much as possible. The main goal of project management is to improve project performance by identifying, evaluating and systematically managing the project, in relation to risk (Farzad Rahimi Mogoei and Hadi Jahangiri, 2015).

The success of a project is measured by the results, which are supposed to be achieved based on the project's goals in terms of time, cost, and quality. Accordingly, the desired project results achievement depends on the way the project risks are handled. Many companies start a project with only a vague view of the project's goals and priorities.

Each risk management process requires the employment of analysis, planning, control, and management techniques for which investment is necessary. In addition, in order to implement this process in the organization, the conditions need to be provided and the necessary infrastructures (including technical, support, computer, databases, and procedures) and processes must be prepared. Awareness and understanding of the potential and importance of project risk management should be clearly and distinctly considered in project management decisions (Majid Jaberi and Ahad Nazari, 2015). Many studies have been undertaken in these areas, which are mentioned as follows.

In a study entitled "analysis of safety risks of construction projects using integrated method", using the judgment of safety experts and project supervisors and through questionnaires, Mohajeri (2016) identified twenty activities with risk potential, ten accidents caused by these activities and twelve causes of accidents. Finally, excavation activities and working at high altitude were recognized as the most dangerous activities in terms of safety, and some solutions were provided to improve the safe conditions and prevent accidents caused by these activities.

Hatefi (2016) conducted a study entitled "a practical method for ranking and selecting a project portfolio based on qualitative risk assessment and argued that implementation of projects is a fundamental way to drive organizational strategies, especially in project-based organizations. In such organizations, decision makers are always faced with the problem of choosing a project portfolio, and of course, they tend to direct their limited resources to projects that have the least threat and the most opportunity, given their degree of risk-taking. This study presents a new method for ranking and selecting project portfolios according to the risk orientation of decision makers. In this method, due to the ease of application, the judgment of experts is taken into consideration in the form of qualitative estimates. Also, the proposed method includes a special approach for calculating the level of total risk in which the computational problems of traditional methods are avoided. At the end of the research, the application of the proposed method in the real example of the steel structure industry is analyzed.

In another study entitled "a robust two-objective optimization model for selecting response to project risks and explain model solving methods", Rezaei et al., (2016) define risk management as one of the most effective parts of project management that identifies, evaluates and responds project risks. In recent years, despite the publication of various studies on the response to project risk, few tools and methods have been presented in this field. Therefore, in this study, an optimization model of response to project risk was proposed, which seeks to optimize the two key project criteria including time and cost. The model has two objectives: one is to minimize the total loss expected, including the cost of implementing risk-averse actions on project costs, and the other is to minimize the time-risk effect (maximizing the robustness criterion) according to the free-float standard of activities.

In this model, measures are selected to reduce the risk so that their temporal effect on the time of each activity will be higher than that of their free float. In the following, three precise, heuristic and meta-heuristic solution types were proposed. By creating ten projects in three categories with small, medium and large scale and solving problems through three proposed methods, the results were compared.

In their study entitled “identifying and prioritizing the risks of electricity industry development projects (Case Study: Transmission and Over-Distribution of Khorasan Regional Electricity Company)”, Kolahan et al., (2015) showed that budget shortages, sanctions, and poor selection of project agents are effective risks in their studied projects. In addition, their proposed approach can be applied to other large-scale national projects with appropriate positional changes to manage risks.”

Yousefi et al. (2014) conducted a study entitled “presenting a project risk assessment model using a multi-purpose decision-making approach (Case Study: Assaluyeh Earth Dam Project)”. In this paper, to evaluate the possible risks of the project, a zero-one linear programming model was used with multiple objectives. The proposed model has two purposes: 1) to minimize the expected cost of various risks, and 2) to minimize the expected time from potential risks. The model has also two limitations: 1) the temporal effect of the risks must not exceed the total expected temporal value of the risks, and 2) controlling the cost effect of the risks to be smaller or equal to the expected value of the risk’s occurrence cost. To solve the proposed model, the L-P metric method is suggested. The results of solving the model for a case study are presented in a dam construction project in Assaluyeh region, which includes optimal Pareto answers.

Nazari et al. (2013) conducted their study as “designing a risk management model in a project-oriented organization” and report that the lack of certainty in industrial environments will increase the complexity of project implementation and management in organizations, leading to make risk management unavoidable. In this regard, several books and articles have presented general risk management models. However, in order to design and implement a risk management model in a particular organization, the conditions and characteristics of that organization must be considered. This research seeks to design a model in a large project-oriented industrial organization in Iran. For this purpose, first, the types of available models were reviewed and compared. Then, the characteristics and conditions of the organization were identified and analyzed through interviews and questionnaires. Next, using the existing models, the model processes were designed and validated along with the structure and details of the implementation of each process. The proposed model can be generalized to similar organizations.

In their study entitled “Safety Risk Assessment in Mass Housing Projects Using Combination of Fuzzy FMEA, Fuzzy FTA and AHP-DEA”, Ardershir et al., (2013) argue that ranking the risks and their most important (i.e. falling from height) in the present study is consistent with previous research as well as the report of the Iranian Social Security Organization. In addition, the root causes of major risks are consistent with those found in similar studies. On the other hand, the validation of the research was confirmed by the risk assessment group. Therefore, this model (taking into account the current safety situation) can help construction safety professionals to identify risks and their root causes, providing accurate risk control tools.

Tiller and Cook (2012) in their study entitled "Portfolio risk management" recognize project risk management as an essential element to tackling environmental challenges. The written publications offer an expensive portfolio-specific landscape for risk management in the portfolio project. However, there is very little research on project risk management and its success. Their study examines how portfolio risk management affects project success. Using a sample of 176 companies, the study provides evidence that portfolio risk identification, portfolio risk management process compliance, and risk management culture directly affect risk transparency.

Hemanata et al., (2012) undertook their study as "analyzing factors affecting delays in Indian construction projects" and found that the delaying variables of construction projects as follows: insufficient commitment, inefficient management, poor coordination, poor planning, poor communication, non-standard contracts, slow decision-making, low employees' productivity and rework.

Zheng et al., (2012) used fuzzy hierarchical analysis method to assess work safety in hot and humid environments.

Nieto-Morote et al., (2011) present a new way of risk analysis for a construction project that deals with risks in a complex situation where risk assessment data is incomplete or unattainable. The hierarchical method was examined for assessing the weight of risks using two distances. This method is ideal to minimize the difference between the value of the priorities obtained directly from the members of the evaluation team and the conventional value.

In 2010, Butcher reviewed employers' views through interview with them on important factors in a contractor's good performance. From the employers' point of view, the contractor's behavioral factors are the most important inputs to achieve the main output of the project. These factors include having extensive communication with the employer, having a sense of cooperation and willingness to exchange knowledge as one of the parties involved in project, having constant and integrated organizational culture, promising and keeping contractual obligations and the perception of the employer's needs.

Yeung et al., (2008) believe that senior management's commitments, effective communication, mutual respect and trust, and innovation are the most important performance indicators among construction projects in Hong Kong.

Chabota et al., (2009) conducted a study entitled "cost escalation and schedule delays in road construction projects in Zambia" and found that the variables unfavorable climate change, limited change, technological changes, local state's inflation and pressure, financial processes and problems associated with contractor and contracts.

Zayed et al., (2008) represented the two main sources of risk affecting a high-level highway project at both macro (company) and micro (project) levels and evaluated the effects of each on risks, and offered a risk model for evaluating and prioritizing projects using hierarchical analysis process. Their results show that political risk and financial risk, respectively, have the highest weight at the macro level and emerging technological risks and resources have the highest weight at the micro level. In this article, the risks were prioritized in the contractor's implementation phase and in terms of cost and quality.

Methodology

The present study is considered as an applied research in terms of the purpose of the research. In the present study, it is tried to examine and develop applied knowledge in a specific field, so it can be considered as an applied work. In this research, was initially collected through study sources, including books and authoritative articles in the relevant field.

Statistical Population:

The statistical population is composed of whole group of people, events or things that the researcher wants to investigate (Sakaran, 2007, 296). The statistical population of this study included experts and managers of construction contracting companies (in Bojnourd city).

Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) is a Multi-Attribute Decision Making (MADM) approach, which is used to make a decision and choose an option from the various decision items, according to the indicators determined by the decision maker (Karimi Dastjerdi et al., 2010; Albert and Yaeir, 1990). To implement the AHP, the problem model is initially prepared with the aim of selecting the best option according to the criteria and sub-criteria. Then, the relevant pairwise comparison tables are provided to the experts (Taslimi et al., 2004; Tavari et al., 2008). In using AHP to make decisions on company issues, it may not be correct to use the judgments of just one manager in forming a pairwise comparison matrix that is the basis for decision-making, so multiple experts' opinions are used. In addition, the geometric mean is used to get consensus. Finally, in order to determine validity of the questionnaire (determining the consistency or inconsistency of opinions), validity is examined in terms of the inconsistency rate and the tables with inconsistency rates of less than 0.1, will be accepted (Mehregan, 2008).

Demographic characteristics of respondents and statistical population

Table 1: Demographic characteristics of respondents (Source: Author)

		Frequency	**Percentage**
Gender	**Male**	28	70%
	Female	9	30%
Age	**20-30 years old**	3	10%
	30-40 years old	17	57%
	40-50 years old	6	20%
	Older than 50	4	13%
Education level	**High School Degree**	0	0%
	Associate degree	0	0%
	Bachelor	11	37%
	Master	13	43%
	PhD	6	20%

The status of respondents in terms of gender

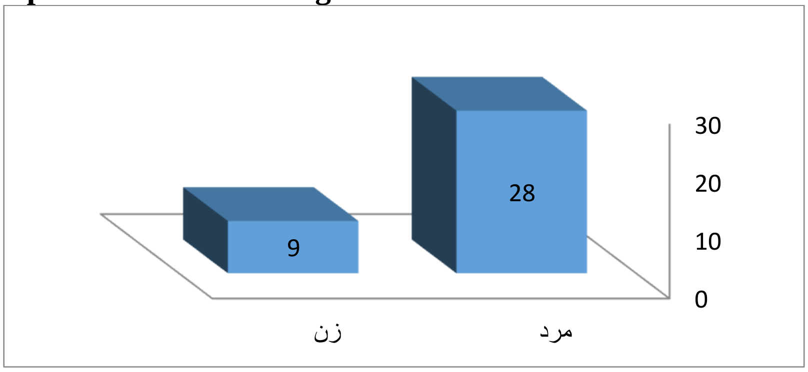

Figure 1: Frequency chart of respondents' gender status (Source: Author)

The status of respondents in terms of age

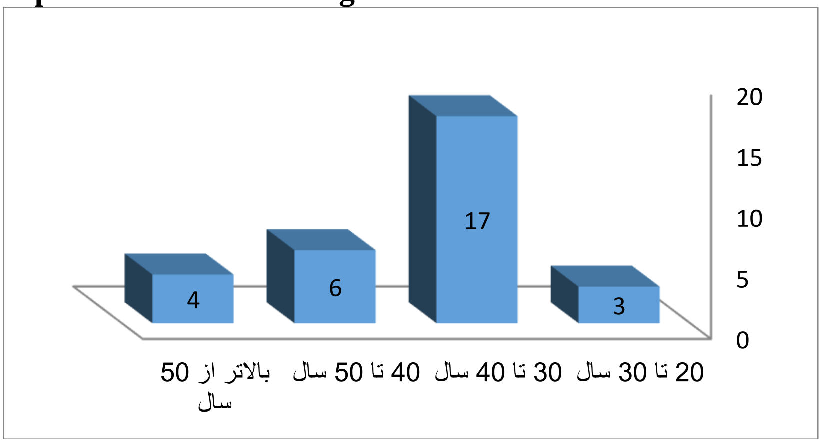

Figure 1: Frequency chart of respondents' age (Source: Author)

The status of respondents in terms of educational level

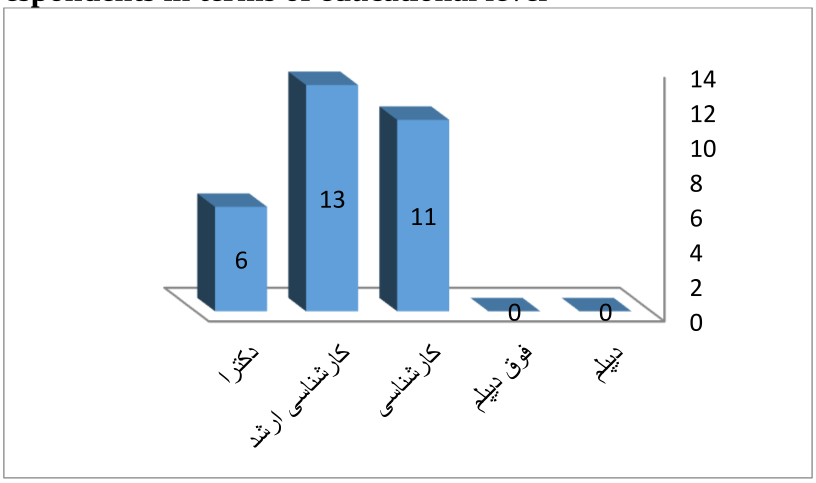

Figure 1: Frequency chart of respondents' educational level (Source: Author)

Discussion

Calculation of the relative weight of the contractor's risk indicators at the project implementation phase

The pairwise comparison matrix of each indicator is presented in Table 2 and Figure 4 according to the risk factor of the contractor during the implementation phase. According to the table and the figure, it is clear that the relationship between all the sub-indicators is mutual.

Table 2: Matrix of pairwise comparisons for Contractor's risk at implementation phase

Contractor's risk at implementation phase	Project cost risks	Operational risks	Risks of timely provision of facilities	Project scheduling risks	Human Resources risks	Quality relevant risks
Project cost risks	$\tilde{1}$					
Operational risks		$\tilde{1}$				
Risks of timely provision of facilities			$\tilde{1}$			
Project scheduling risks				$\tilde{1}$		
Human Resources relevant risks					$\tilde{1}$	
Quality relevant risks						$\tilde{1}$

Table 3. Prioritization of the main indicators according to the contractor's risk factors in the implementation phase (Source: Author)

No.	Criterion	Weight	Priority
1	Project cost risks	0.240	1
2	Operational risks	0.188	2
3	Human resources relevant risks	0.188	3
4	Risks of timely provision of facilities	0.168	4
5	Project scheduling risks	0.143	5
6	Quality relevant risks	0.127	6

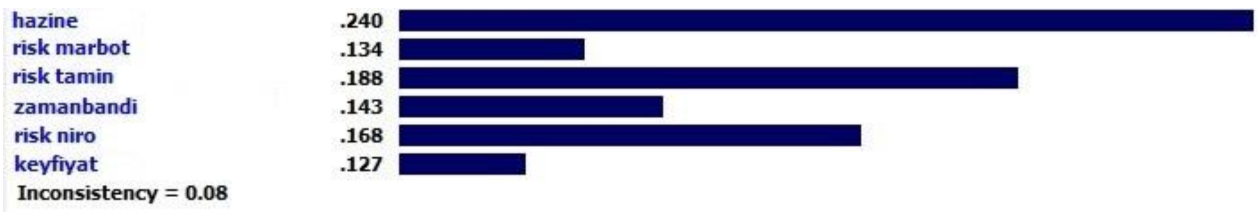

Figure 4: Prioritization of the main indicators according to the contractor's risk indicators in the implementation phase

According to the table above and given the main weight obtained, the risk components including project cost risks, operational risks, risks of providing timely facilities, project scheduling risks, human resources-relevant risks, quality relevant risks, respectively, have the highest and lowest importance in the group. On the other hand, considering that the inconsistency rate obtained is 0.08, which is smaller than the standard limit 0.1, therefore, the above questionnaire has been completed by the respondents with a high accuracy.

Calculating the relative weight of project cost risk indicators

The pairwise comparison matrix of each of the indicators is presented in Table 4 and Figure 5 according to the risk factor of the project cost. According to the table and the figure, it is clear that the relationship between all the sub-indicators is mutual.

Table 4: Matrix of pairwise comparisons for project cost

Project cost risks	Budget shortages	Inability to settle the receivables of partial contractors	Delay in payment of contractor's invoice cost	Increased overhead costs due to delay in notification of drawings	Contractor's increased overhead costs due to delay of employer in importing materials	Poor wage and salary systems
Budget shortages	$\tilde{1}$					
Inability to settle the receivables		$\tilde{1}$				
Delay in payment of contractor's invoice cost			$\tilde{1}$			
Increased overhead costs due to delay in notification of drawings				$\tilde{1}$		
Contractor's increased overhead costs due to delay of employer in importing materials					$\tilde{1}$	
Poor wage and salary systems						$\tilde{1}$

Figure 5: Prioritization of the main indicators according to the risk factors of the project risk

Table 5. Prioritization of the main indicators according to the risk factors of the project risk (Source: Author)

No.	Criterion	Weight	Priority
1	Budget shortages	0.204	1
2	Inability to settle the receivables	0.183	2
3	Delay in payment of contractor's invoice cost	0.170	3
4	Increased overhead costs due to delay in notification of drawings	0.154	4
5	Poor wage and salary systems	0.147	5
6	Contractor's increased overhead costs due to delay of employer in importing materials	0.141	6

According to above table and the calculations resulted from the main weight , the following components respectively showed the highest and lowest importance in project cost group: budget shortages, inability to settle the receivables of partial contractors, delay in payment of contractor's invoice cost, increased overhead costs due to delay in notification of drawings, contractor's increased overhead costs due to delay of employer in importing materials and poor wage and salary systems. On the other hand, considering that the inconsistency rate obtained is 0.04, which is smaller than the standard 0.1, therefore, the above questionnaire has been completed with high accuracy by the respondents.

Calculation of relative weight of quality risk indicators

The pairwise comparison matrix of each indicator is presented in Table 6 and Figure 6, according to the quality-risk factor. According to the table and the figure, it is clear that the relationship between all the sub-indicators is mutual.

Table 6: Matrix of pairwise comparisons for project quality

Project quality risks	Poor quality of work performed by the contractor	Poor tests in concrete's compressive strength test	Low quality of studies
Poor quality of work performed by the contractor	1̃		
Poor tests in concrete's compressive strength test		1̃	
Low quality of studies			1̃

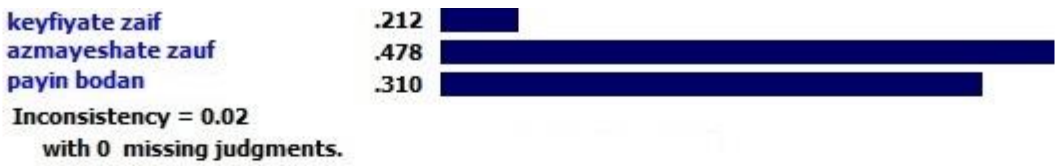

Figure 6: Prioritization of main indicators according to the quality risk factor

Table 7: Prioritization of the main indicators according to the quality risk factor

No.	Criterion	Weight	Priority
1	Poor quality of work performed by the contractor	0.478	1
2	Poor tests in concrete's compressive strength test	0.310	2
3	Low quality of studies	0.212	3

According to above table and the calculations resulted from the main weight , the following components respectively showed the highest and lowest importance in project quality group: poor quality of work performed by the contractor, poor tests in concrete's compressive strength test and low quality of studies. On the other hand, considering that the inconsistency rate obtained is 0.02, which is smaller than the standard 0.1, therefore, the above questionnaire has been completed with high accuracy by the respondents.

Conclusion

Risk management has been defined as follows: "a systematic planning process to identify, analyze, respond, and monitor the project risks". Such a management includes processes, tools, and techniques that help the project manager maximize the likelihood of positive events results and minimize that of harmful events results. Using the full risk management process, it can be argued that it is the project manager person who oversees the uncertainty of the project, and the conditions and events must not engage the management. Risk management, in any project of any kind, needs to be implemented and thus, reducing the possible losses as much as possible. The main goal of project management is to improve project performance by identifying, evaluating and systematically managing the project, in relation to risk. Therefore, in this research, this phenomenon was investigated. The statistical population of this study composed of experts and managers of contracting companies (in Bojnourd cty). The present study was conducted based on an Analytic Hierarchy Process (AHP). Upon calculations, it was observed that according to the main weight obtained in project implementation phase, the components project cost risks, operational risks, risks of providing timely facilities, project-scheduling risks, human resources-specific risks and quality risks respectively have the highest and the lowest importance in this group. The calculations resulted from the main weight also indicated the following components respectively with the highest and lowest importance in project cost group: budget shortages, inability to settle the receivables of partial contractors, delay in payment of contractor's invoice cost, increased overhead costs due to delay in notification of drawings, contractor's increased overhead costs due to delay of employer in importing materials and poor wage and salary systems. The main weight resulted calculations also showed the following components with the highest and lowest importance in the quality group, respectively: poor quality of work performed by the contractor, poor tests in concrete's compressive strength test and low quality of studies.

References

1. Ardeshir A, Amiri M, Mohajeri M. Safety Risk Assessment in Mass Housing Projects Using Combination of Fuzzy FMEA, Fuzzy FTA and AHP-DEA. Bimonthly Journal of Occupational health. 2013; 10 (6) :78-91
2. Jahangir, Mohammad, Mazaheri, Tahmasb, (2006). Risk Management of Price Offering in Construction Projects, International Project Management Conference. Ariana Research Group Publications.
3. Sakaran, Oma, (2002), Research Methods in Management, translated by Mohammad Saebi and Shirazi, 1st edition, Tehran, Public Management Training Center.

4. Fleming, Kontin W., (2007) "Project Procurement Management" Translators: Zahra Ghazi Mirsaeed, Vesal Rezaei, Sara Derakhshan, 1st Edition, Tehran, National Petrochemical Company Publications.
5. Farhad Kolahan , Ebrahim Rezayinik , Marziyeh Hassani Doughabadi , Hamid Ramezanpour , Amirreza Tajadod. (2015). Identifying and prioritizing of risks in electric industry development projects (Case study: transmission and high distribution of Khorasan Regional Electric Co.). Journal of Industrial Engineering. 49(1):107 – 116.
6. Mohajeri, M., Ardeshir, A. (2016). Analysis of construction safety risks using AHP-DEA integrated method. Amirkabir Journal of Civil Engineering, 48(3), 217-226. doi: 10.22060/ceej.2016.608
7. Mehregan, Mohammad Reza, "Advanced Operational Research", Tehran, University (Daneshgah) Book Publications, First Edition, 2004.
8. Nazari Ahad, Jaberi Majid, Amal Nik Mohsen Sadegh. (2013). Designing Risk Management Model in a Project-Based Organization. Journal of Industrial Engineering, Volume 47, Number 1.
9. Mohammad Ali Hatefi. (2016). Introducing an Applicable Technique for Ranking and Selecting Project Portfolio, based on Qualitative Risk Assessment. Journal of Industrial Engineering. 50(1):2016
10. Yousefi O, Naseri P, Nilipour Tabatabaei SA. (2014). presenting a project risk assessment model using a multi-purpose decision-making approach (Case Study: Assaluyeh Earth Dam Project). Journal of Industrial Engineering. 48(1)
11. Chabota., K ,Mundia., M,& M .Kanyuka.(2009).”Cost escalation and schedule delays in road construction projects in Zambia”.international journal of project management.VOL.27.PP.522-531.
12. D. A. Butcher, "Excellent contractor performance in the UK construction industry", Engineering, Construction and Architectural Management, 17 (1), 35-45, 2010.
13. Hemanata., D, Anil sawhney, K.C. Iyer & S. Rentala. (2012).”Analysing factors affecting delays in Indian construction projects”. International journal of project management.VOL.30,PP.479-489.
14. J. Yeung, A. Chan, D. Chan, "Establishing quantitative indicators for measuring the partnering performance of construction projects in Hong Kong", Construction Management and Economics, 26 (3), 277-301, 2008.
15. Nieto-Morote, A. and Ruz-Vila, F. (2011). “A fuzzy approach to construction project risk assessment.”*International Journal of Project Management*, 29., 220–231.
16. Zayed,Tarek., Amer,Mohamed. and Pan,Jiayin. (2008).“Assessing risk and uncertainty inherent in Chinese highway projects using AHP.” *International Journal of Project Management* ,26, 408–419.
17. Zheng, G.; Neng, Z.; Zhe, T.; Ying, C. and Binhui, S;"Application of a Trapezoidal Fuzzy AHP Method for Work Safety Evaluation and Early Warning Rating of Hot and Humid Environments," *Safety Science*, Vol.50, No. 2, pp. 228–239, 2012.