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Project Risk Assessment Framework

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Abstract

This study presents a framework for calculating the risk of various projects, especially projects under uncertain circumstances. First, the related literature is reviewed and then the relationship between risk and projects is examined. Using a case study an approach is provided to determine the project risk in uncertain circumstances where sufficient data is not available for decision-making. In the new proposed method, instead of using a purely qualitative method, Dempster-Shafer theory has been used because of the limited data for decision making. Finally, the proposed method is examined based on a construction company and the results are presented.

Introduction

A decision maker in the process of decision making always faces uncertainties. Project management is also a kind of decision-making in which responsible people including project managers always face the problem of risk assessment. Several studies have been conducted in the context of uncertainty; for example, Oberkampf examined variety of uncertainties and differences between them (Oberkampf et al.,2000). According to all the researches that have been done there is not a complete consensus on the best model to deal with uncertainty. Interval variables are offered for the determination of uncertainty in the previous studies; for example, using inherent upper and lower prediction method scan (Kyburg,1998). Some of the most important methods to predict the future and deal with uncertainties are Probability Theory, Control Theory (Dempster,1967). Model of Belief (Shafer,1976), and Base Theory (Berger, 1985). This study uses the method of Dempster-Shafer theory that is usually used for decision-making under uncertain circumstances and when there is little information about the corresponding issue. This method is used to determine minimum and maximum levels of project risks in terms of cognitive uncertainties. This means minimum available information is used to obtain suitable criteria for decision-making.

Literature Review

The range of uncertainty in projects is considerable and most of the project activities from the early stages of the project life cycle deal with difficulties to explain and make decisions about possible actions against the uncertainties of the project. A part of uncertainty in projects is concerned with possible changes in project performance criteria such as cost, time, and

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quality. In addition, uncertainty in projects can be related to issues such as ambiguity in understanding the behavior of agents and institutions in the project, lack of information, lack of clear structure, assumed hypotheses, known and unknown sources of diversion in project and many other issues.

Investment Culture defines risk as potential loss of investment that may be calculated. An applied definition of risk (Raftery,1999) is "risk and uncertainty express the position that a real product or activity seems different from anticipated or estimated amount". It is possible for the product to be better or worse than the initially forecasted value. A more comprehensive definition of risk is stated by (Chapman,1997) in which risk is defined as expression of the probability of financial and economic profit or losses of damages and the culture and context of risk is at exposure. Dictionary of Investment also recognizes risk as potential loss of investment that can be calculated. Galitz defines risk as any fluctuation in any gain(Galitz,1996). The above definitions make it clear that possible future changes for a particular index either positive or negative encounters us with risk.

First, Harry Markowitz based on a quantitative definition presented a numeric index for risk. He defined risk as multi-period standard deviation of a variable. There is another perspective about risk, which focuses only on the negative aspects of volatility. In multiple articles and sources, the issue of risk assessment especially the risk of drilling constructions and tunnels has been considered. In most studies, the classic method has been used to assess the risk (ITA,2004). Often, the results of the occurrence are studied on the time and cost of the project. Some of the researchers have expressed the cost and time of underground and tunnel projects with regard to risk as a probability function (Reilly&Parker,2007). In order to remove restrictions of the number of criteria in this method, other criteria such as "the organization capability to respond to risk" (McDermott et al., 2009), "The degree of uncertainty of estimation" (Klein & Cork,1998) has also been proposed in assessing other projects. Probability and impact on the quality of the project have also been used in ranking. Other complementary measures such as being manageable and the proximity of the project risks have been considered in some other studies (Pertmaster Software,2002). In the field of environmental risk assessment, the criteria for socio-economic effects and environmental impacts have also been used (Xu & Liu,2009). In some of the resources, Risk Breakdown Structure has been discussed in the drilling operations and it is stated in the form of a triple (Duddeck,1987) or quadruple systems. In another study, a comprehensive Risk Breakdown Structure is provided for tunneling projects and all of the related risks have summed up in order to use the capabilities of multi-criteria decision-making methods, including the use of Fuzzy methods (Sayadi et al., 2010).

Since 1977, a considerable number of articles and books (Kuo & Prasad,2000) about optimizing decision-making and system reliability and avoiding risks are provided taking into account the costs. In the optimization decision-making models, it is attempted to obtain the reliability required for decision outcomes at a minimum cost. While these models are not necessarily risk-based models because they do not integrate the losses associated with defeating the purpose of the system in their results, they obtain the least required reliability from a balance between the costs arising from the failure and costs of achieving the results that have been authenticated. In this case various options are compared and one of them is selected. There are also researches on the implications of the Probability theory to optimize decision making in risk conditions, e.g. fuzzy techniques (Ravi,2000). Todinov has presented some models in the field of potential losses because of the multiple decision failures(Todinov,2003) He proposed a model to determine optimal risk rate at obtained minimum total cost. In addition, he has provided models and algorithms for failure detriment of unreliable and complex system.

According to the traditional definition, risk is obtained by multiplying the probability of failure by the result of failure that can be shown as follows:

$$Ri = P * C \quad (1)$$

To investigate the association between the certainty of success and system risk at a given level of results, if $R_{i\max}$ is defined as the maximum acceptable risk of failure and $p_{f\max}$ is the maximum acceptable risk, and c shows the value of failure average cost (results). Equation 1 can be illustrated as follows:

$$p_{f\max} = \frac{R_{i\max}}{C} \quad (2)$$

To have a risk level below the maximum risk $R_{i\max}$, probability of failure p_f must be less than maximum $p_{f\max}$ and can be shown as follows:

$$p_f \le p_{\max} \quad (3)$$

$$P_f \le \frac{Ri_{\max}}{C}$$

According to the above equation, probability of failure must be lower than the maximum acceptable level. To design and build confidence in the system output, the components which have larger losses should be placed at higher level of confidence. This decision making approach is based on risks. Given that the confidence in the decision is defined by the probability of success of the decision results, the probability of failure and minimum confidence in decision can be obtained from the following relation:

$$R_{\min} = 1 - P_{f\max} \quad (4)$$

$$R_{\min} = 1 - \frac{Ri_{MAX}}{c}$$

According to the above mentioned equations, the probability of decision failure should be at minimum required level for the risks to remain at an acceptable level. In the absence of data, is not easily possible to receive probability of decision failure and success, so using theory of probability is not possible.

Among the methods of decision-making suggested under conditions of uncertainty, Dempster-Shafer theory, which is also called as believe theory, presents a strong framework to display and express uncertainty of imperfect knowledge. The use of belief theory began with Dempster's work. Mathematical Theory of belief was defined delicately by Shaffer, although in the past decades, Bayesian statistical inference theory (Bayes,1763) partly has covered Dempster-Shafer theory. Dempster-Shafer studies have had many applications as a technique for modeling under uncertainty. Different approaches are provided to manage uncertainty. For example, Shortliffe proposed a model that manages uncertainty and has certain factors (Shortliffe & Buchanan,1975). The Dempster–Shafer theory allows combining evidence from different sources and arriving at a degree of belief that takes into account all the available evidence. It was represented by a belief and plausibility function.

When we have incomplete knowledge, using uncertainty methods is more suitable. Fedrizzi offered studies on fuzzy prioritization and using interval value to display the comments and judgments of specialists through cumulative distribution (Fedrizzi & Kacprzyk,1980). Any method that is used to manage uncertainty has its own advantages and disadvantages associated with it. For example, Casselton have discussed about the problems caused by the Bayesian Analysis that arise from lack of information (Casselton & Luo,1992) and Klir has criticized an illustration of probability of uncertainty to derive the necessary knowledge (Klir,1989). Among these methods, Dmpstrv-Shaffer theory has had many applications when information is taken from several sources and it is used to extract knowledge.

Further, the basic allocation of probability has a different definition of classic probability and is defined as a map in the [0-1] distance. These principles can be displayed by the following equations:

$$m(A) \rightarrow [0,1] \quad m(\phi) = 0 \quad \sum_{A \subseteq \Theta} m(A) = 1 \qquad (5)$$

3.2 Belief function

Upper and lower bounds of distance can be determined by the basic allocation of probability, which includes set probability limited by two other un added sizes of belief and probability. General relations between bpa and beliefs may be shown as follows:

$$bel(A) = \sum_{B \subseteq A} m(B) \quad bel(\varphi) = 0 \quad bel(1) = 1 \qquad (6)$$

Upper bound or probability function of sum of basic allocation of probability of subset of B is written through $A, i.e, B \cap (A) \neq \phi$ and as follows:

$$pl(A) = \sum_{B \cap A \neq \phi} m(B) \qquad (7)$$

Probability function is related to belief function through doubt function. As it is defined in the following equation:

$$pl(A) = 1 - Bel(\neg A) \quad pl(A) = 1 - doubt(\neg A) \qquad (8)$$

In addition, the following relationships exist between belief and probability functions in all situations.

$$pl(A) \geq bl(A) \quad pl(\phi) = 0 \quad pl(\theta) = 1 \quad pl(\neg A) = 1 - bel(A) \qquad (9)$$

Belief distance represents a range that probability may be wrong and it is determined by reducing probability and belief distance. The narrower range the belief distance has, the more accurately it represents probabilities. If the probability is a unit $bel(A) = Pl(A)$, then belief range equals the probability theory. If $U(A)$ distance is $[0,1]$ distance, it means that no information is available. If the distance is $[1,1]$, it means that A is fully approved by the basis allocation of probability.

Case Study

A construction company that works in excavation operations section intends to estimate the project risk and proposes a specific risk management program. Because of the complexity of the project, both the company and its clients will incur loss if the process is interrupted. The identified risks are shown below in a tree diagram.

To start the analysis project fault tree is used. Available data for similar risks in the previous projects have been collected over ten years. This data is limited and direct decision making is not possible through statistical methods. In statistical methods, first objective and sufficient data should exist to calculate and state the project risk using mathematical formulas and models. Although this method is a certain way to determine the project risk but because of limitations such as being expensive and time-consuming, lack of sufficient objective data, high sensitivity to quantitative data it was impossible to use mathematical methods and models. Table 1 describes project risks based on their causes and effects

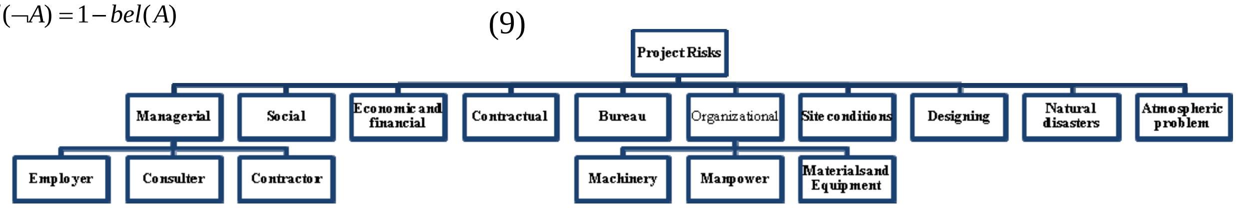

Fig 1. Project risks

Table 1. Types of project risks

Activity Code	Type of risk	Cause	Risk	Effect
M1	**Managerial**	Weak Financial interactions of Contractor with Contractor	Efficiency reduction or cessation of work by the contractor	Project Time increase
M2		Weak Financial interactions of employer with Contractor	Efficiency reduction or cessation of work by the contractor	Project Time increase
M3		Low flexibility of Consultant and employer	Rework and compliance with strict and unreasonable requirements	Project Time and cost increase
M4		unrelated work experience of employer	Incorrect estimation of the initial term of the Agreement	Project Time increase
C1	**Contractual**	Unclearness of the scope of the project	Major changes in the volume of activities and Notification of jobs added	Project Time and cost increase
A1	**Foreign Bureaus**	Employer Delays in obtaining permits to carry soil	Interruption in soil transportation and increasing its cost	Project Time and cost increase
A2		employer delay in obtaining a building permit from the municipality	Interruption or delay in the initiation of project	Project Time increase
A3		Disruption in the provision of urban facilities	Stopping part of Operation	Project time increase
A4		Violation of urban regulations	Stopping operations by the municipality or police	Project time and cost increase
E1	**Economic and Financial**	Failure to achieve political consensus	Negative changes in economic indicators	Project cost increase
E2		Lack of appropriate financing of the project by the employer	Efficiency reduction or Work stoppage by contractor	Project time increase – project quality loss
E3		Lack of appropriate financing of the project by contractor	Efficiency reduction or Work stoppage by contractor	Project time increase -project quality loss
S1	**Social**	Dissatisfaction with neighbors	Work stoppage due to neighbors Protests and the need to satisfy them	Project time and cost increase
S2		Lack of allocating appropriate machinery to the project	Doing Related activities with insufficient machinery	Project time increase – project quality loss
S3		Insufficient human resources allocation	Reducing the efficiency of activities	Project time increase
O1	**Organizational**	The strategic importance of the project	The imposition of administrative procedures to comply with the expectations of employer	Project cost increase
O2		strategic importance of other projects	Transferring part of the of required machinery and manpower to other projects	Project time increase – project quality loss
O3		Lack of timely payments to contractor members	Interruptions in the contractor members operations	Project time increase -project quality loss

Table 2. Continued, Types of Projects Identified Risks

Activity Code	Type of risk	Cause	Risk	Effect
F1	**Materials and Equipment**	The need for special materials	Difficulty in providing and using materials	Project time and cost increase
F2		The delay in the Ordering materials	Late provision of Building materials	Project time increase
F3		Low quality of incoming materials to the workshop	The rejection or rework of Building materials	Project time increase– quality loss
D1	**Designing**	The multiplicity of adjacent property	Dealing with unknown effects during the upper levels operation	Project time and cost increase –quality loss
D2		Insufficient time for designing before the start of Operation	Difficulty in implementing in accordance with the drawings designed	Project time and cost increase –quality loss
D3		Ignoring operating conditions in different layers	Lack of strength in anchor design	Project time and cost increase –quality loss
Q1	**Machinery**	Low quality of machinery	Doing Related activities with low efficiency and the need for rework	Project time and cost increase – project quality loss
Q2		Late provision of spare parts	Machinery Work stoppage	Project time increase
Q3		Failure to do periodic visits	The sudden transfer of machinery to Repair distance for major repairs	Project time increase
Q4		Inappropriate Repair and maintenance	Repeated crash of machinery	Project time and cost increase
H1	**Human Resources**	Insufficient work experience of project team	Reducing the efficiency of activities- Mismatch of product with evaluation criteria	Project time and cost increase - Quality loss
H2		Lack of enough accommodation places for workers	Residence of workers out of the workplace	Project time and cost increase
H3		Delay or absence of key personnel	Cessation of part of Operation	Project time increase
H4		Non-payment of wages on time	Workers strikes	Project time increase
S1	**Site Conditions**	Higher groundwater level of the arena floor	Reducing the efficiency of operations and the need for drainage schemes	Quality loss
S2		The large volume of hand soil in upper terraces	Local instability	Project time and cost increase - Quality loss
S3		The weakness of the adjacent buildings	The need for additional retrofitting	Project time and cost increase
S4		The supply of electricity by generator	Stop operations due to generator failure	Project time and cost increase
S5		Simultaneous activities of various kinds in the workshop	Interference and Cessation of Operation	Project time increase – project quality decrease
S6		Lack of proper drainage	Groundwater flow in the workshop	Project time and cost increase
W1	**Atmospheric Condition**	Heavy rain or snow	machinery moving Difficulty	Project time increase
W2		extreme cold	Compressor failure	Project time increase

Dempster-Shafer Calculations in Basic Estimation of Probability

Although there is some information about the probability of project failure, it is not possible to calculate the probability of failure by traditional method, i.e. probability theory. Therefore, Dempster-Shafer theory is considered. According to the review of literature, the probability of project failure can be classified into three severity levels:

Low (L) - There is a low probability that the failure will occur in the given time period.

Medium (M) - There is an average probability that the failure will occur in the given time period.

High (H) - There is a high probability that the failure will occur in the given time period

Set of possible events will be placed within the framework of $\theta = \{L, M, H\}$ set. Possible scenarios based on the above hypothesis can be placed in eight sub-categories: $\{\emptyset\},\{L\},\{M\},\{H\},\{L,M\},\{L,H\},\{M,H\},\{L,M,H\}$. Set of basic allocation of probability for failure in the studied project are shown in Table 1.

Any basic allocation of probability is limited by two sizes of belief and plausibility. These specified limits are upper and lower bonds of basic allocation of probability. Having Table 1, which represents the basic allocation of probability of failure for each of the project activities, and using equations 8 and 9, we can simply obtain belief function and plausibility of failures. Results for a number of elements of project risk tree depicted in Table 2, have been brought. To determine the probability of failure of any of the potential risks based on the table of belief and plausibility function, the distance, which has the highest belief function, is selected. As belief function determines lower and the minimum probability according to the available data, we are certain of its existence.

Table 3. Basic Probability Assignment for Occurrence

BPA	Project Activity Codes (cost)																		
	M3	A1	A4	E1	S1	O1	F1	D1	D2	D3	Q1	Q4	H1	H2	S1	S2	S3	S4	S6
L	0.1	0	0.1	0.2	0.5	0.1	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0	0	0.3	0.1	0.1	0.2
M	0.5	0.6	0.3	0.1	0.4	0.3	0.3	0.2	0.1	0.3	0.4	0.4	0.4	0.2	0.1	0.3	0.3	0.5	0.1
H	0.2	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0
L,M	0	0.3	0.4	0.5	0.1	0.6	0.4	0.4	0.5	0.4	0.3	0.3	0.3	0.4	0.6	0.4	0.4	0.3	0.6
L,H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M,H	0.2	0	0.1	0.2	0	0	0.1	0.2	0.1	0	0	0	0.1	0.4	0.3	0	0	0.1	0
L,M,H	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0.1

Table 4. Belief function and the probability calculations

BPA	Project Activity Codes (cost)															
	M3		A1		A4		E1		S1		O1		F1		D1	
	l bel	plu	l bel	plu	l bel	plu	l bel	plu	l bel	plu	l bel	plu	bel	plu	bel	plu
L	0.1	0.1	0	0.3	0.1	0.5	0.2	0.7	0.5	0.6	0.1	0.7	0.2	0.6	0.2	0.6
M	0.5	0.7	0.6	0.9	0.3	0.8	0.1	0.8	0.4	0.5	0.3	0.9	0.3	0.8	0.2	0.8
H	0.2	0.4	0.1	0.1	0.1	0.2	0	0.2	0	0	0	0	0	0.1	0	0.2
L,M	0.6	0.8	0.9	0.9	0.8	0.9	0.8	1	1	1	1	1	0.9	1	0.8	1
L,H	0.3	0.5	0.1	0.4	0.2	0.7	0.2	0.9	0.5	0.6	0.1	0.7	0.2	0.7	0.2	0.8
M,H	0.9	0.9	0.7	1	0.5	0.9	0.3	0.8	0.4	0.5	0.3	0.9	0.4	0.8	0.4	0.8
L,M,H	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 5. Continued

BPA	Project Activity Codes (cost)															
	D2		D3		Q1		Q4		H1		H2		S1		S2	
	bel	plu	bel	plu	bel	plu	bel	plu	bel	plu	bel	plu	bel	plu	bel	plu
L	0.3	0.8	0.3	0.7	0.3	0.6	0.3	0.6	0.2	0.5	0	0.4	0	0.6	0.3	0.7
M	0.1	0.7	0.3	0.7	0.4	0.7	0.4	0.7	0.4	0.8	0.2	1	0.1	1	0.3	0.7
H	0	0.1	0	0	0	0	0	0	0	0.1	0	0.4	0	0.3	0	0
L,M	0.9	1	1	1	1	1	1	1	0.9	1	0.6	1	0.7	1	1	1
L,H	0.3	0.9	0.3	0.7	0.3	0.6	0.3	0.6	0.2	0.6	0	0.8	0	0.9	0.3	0.7
M,H	0.2	0.7	0.3	0.7	0.4	0.7	0.4	0.7	0.5	0.8	0.6	1	0.4	1	0.3	0.7
L,M,H	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 6. Calculation of belief function and the plausibility to consequences for a number of project risks

Consequence Impact	Project Activity Codes (cost)															
	M3		A1		A4		E1		S1		O1		F1		D1	
	bel	plu	bel	plu	bel	plu	bel	plu	bel	plu	bel	plu	bel	plu	bel	plu
i	0.1	0.2	0	0.1	0	0.1	0.3	0.5	0.4	0.6	0.1	0.4	0.1	0.4	0.1	0.4
o	0.6	0.9	0.3	0.7	0.1	0.5	0.1	0.7	0.1	0.6	0.3	0.7	0.4	0.9	0.4	0.9
a	0	0.2	0.3	0.6	0.5	0.8	0	0.4	0	0.4	0.2	0.3	0	0.2	0	0.2
i,o	0.8	1	0.4	0.7	0.2	0.5	0.6	1	0.6	1	0.7	0.8	0.8	1	0.8	1
i,a	0.1	0.4	0.3	0.7	0.5	0.9	0.3	0.9	0.4	0.9	0.3	0.7	0.1	0.6	0.1	0.6
o,a	0.8	0.9	0.9	1	0.9	1	0.5	0.7	0.4	0.6	0.6	0.9	0.6	0.9	0.6	0.9
i,o,a	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

The second step to determine the risk of the project is to obtain intensity and impact of risk. Intensity is divided into three levels: minor (i), when the intensity of failure is negligible, moderate (o), when the intensity of failure is moderate and though it may lead to great losses it can be overcome, and major (a) when the intensity of failure is high and it may lead to crisis in the project. Set of events will be placed within the framework of $\theta=\{i,o,a\}$. Possible scenarios based on the above hypothesis can be placed in eight sub-categories: $\{\varnothing\},\{i\},\{o\},\{a\},\{i,o\},\{i,a\},\{o,a\},\{i,o,a\}$. Set of basic allocations of probabilities for intensity of failure in planning for the studied project, similar to the method of obtaining probability is achievable. According to the results of equivalents 6 and 7, belief and plausibility function of project activity codes can be obtained as shown in Table 3. Intervals specified in the table represent the values that have been approved using the existing data

Determining Risk Scope Using a Risk Assessment Matrix

After determining the range of the probability and the intensity of the project failure, using a risk assessment matrix we can obtain risk level of any possible risks. In the recommended pattern, we may put any amount of interval probabilities in a range (tables 4 and 5). Rating this range in tables 4 and 5 starts from small and reaches maximum. After combining the two tables 4 and 5 and drawing it in two-dimensional coordination's, a diagram of risk is achieved. In this diagram, X axis is related to the results and the Y axis shows the probability of failure. Any part of this diagram will represent the risk of failure of any of the codes of the project activities. For example, calculations for managerial risk (low flexibility of consultant and employer) that is shown by M3 in table 1. Belief function of table 3 shows that probability of failure for M3 is moderate-major. According to table 3, it is also concluded that at the event of occurrence, losses from it for the organization is at the range of moderate-major. According to the risk diagram in Figure 3, it can be seen that risk of “low flexibility of consultant and employer” or the M3 in terms of the results are placed in a major range.

After obtaining the risk of each activity code, there are various administrative procedures, to choose. Risk is either at acceptable or unacceptable level. If the system risk is unacceptable, there are three main options: control, separation, and transfer of risk

An organization, identifying and categorizing project risks can reduce, control or transfer project risks. Using a successful assessment they can determine the risk of the projects. To control and reduce the risk of failure of activities that are at unacceptable level of risk, two main strategies can be used

Table 7. The X axis in the risk matrix grading (grading results)

(i) Negligible	(i,o) Moderate-Negligible	(o&i,a) Moderate	(o,a) High-Moderate	(a) High
[0-0.2]	[0.2-0.4]	[0.4-0.6]	[0.6-0.8]	[0.8-1]

Table 8. The Y-axis matrix of risk (probability of failure)

(L) Low	(L,M) Moderate- Low	(M&L,H) Moderate	(M,H) High - Moderate	(H) High
[0-0.2]	[0.2-0.4]	[0.4-0.6]	[0.6-0.8]	[0.8-1]

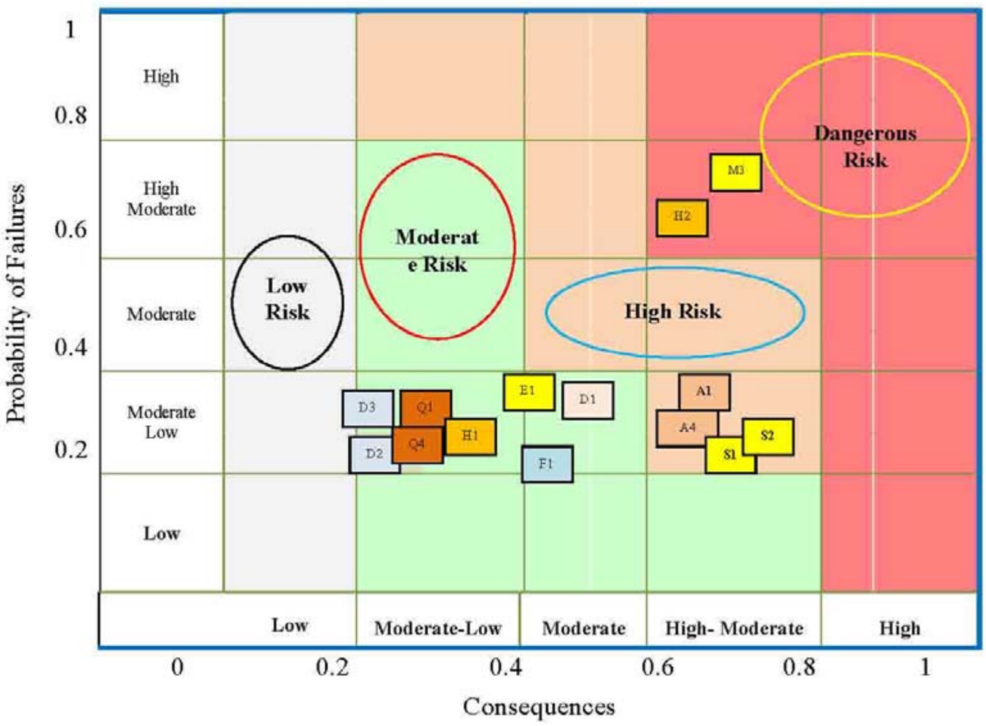

Figure 2: The risk graph to determine the risk of project activities

Table 9: Calculated risk for a number of activities using the distance of belief

Project Activity	Calculated Risk		
	[2] **Probability of Failures**	[1] **Consequence**	Risk[1]
Managerial (M3)	[0.6-0.8]	[0.6-0.8]	Dangerous
Human resources (H2)	[0.6-0.8]	[0.6-0.8]	Dangerous
Foreign bureaus (A1)	[0.2-0.4]	[0.6-0.8]	Great
Foreign bureaus (A4)	[0.2-0.4]	[0.6-0.8]	Great
Site conditions (S1)	[0.2-0.4]	[0.6-0.8]	Great
Site conditions (S2)	[0.2-0.4]	[0.6-0.8]	Great

In the risk diagram (Figure 3), the position of different activities of excavation project has been drawn. As it is clear in the matrixes, H2 and M3 activities have been placed in the major risk section and dangerous area. There are two ways to displace and reduce risk, either to have changes in the possible consequences of failure and face reduction or to make changes for probability of failure. The considerable issue in the above diagram is that any movement in the horizontal direction, i.e. the X-axis is related to the results of the failure. While any changes in the vertical direction, i.e. the Y-axis is related to the probability of the project failure and according to the wishes of decision-maker. Therefore, in using risk analysis to control and reduce the risk of equipment, it is possible to bring down project risk by making changes and adopting measures.

Conclusion and Recommendations

The risk of project activities is one of the fundamental issues in project risk management. Project risk management is a method that helps to design appropriate options to minimize the risk. Unpredictable failures always create risk for a project but this failure is associated with the probability and any positive change in the performance will reduce the probability of the project failure. This study uses Dempster-Shafer theory that is one of the methods used in the conditions of uncertainty. In this research the excavation projects were investigated and the level of risk of failure was determined for different activities. Conclusion is that critical activities can be categorized and identified based on the level of risk. In this case, an acceptable level of risk is selected and characterized. Then, reliability allocation strategy is prioritized based on the risk of equipment, which will help to reduce over-all risk of projects. For instance, a set of actions that can be performed on a number of activity codes are given in table 10.

Table 10 . Improvable areas for a number of activities

A number of project activities	Assessed risk	**Improvable areas**	Strategy
Managerial (low flexibility of consultant and employer) M3	Dangerous	More earning the trust of employer and consultant by contractor- Full notification of the project status by contractor, more honesty of contractor with employer and advisor in all matters	Risk reduction
Human resources (non-supply of accommo-dation places) H2	Dangerous	advance coordination and planning for the space required for the project at different times and proper coordination with the employer	Risk reduction
Foreign bureaus (employer delay in carrying soil) A1	Big	Getting the necessary permits at the time of start of the project by the employer	Risk Reduction and control
Foreign bureaus (Violation of municipal regulations) A4	Big	Obtaining permits and maps related to gas and utilities & Telecommunications agencies	Risk Reduction and control
Social (dissatisfaction with neighbors) S1	Big	Limiting working hours per day- Reducing the activity of noisy and polluting machinery in neighbors rest time- Guarantee to remove any damage and satisfy them	Risk Reduction and control
Social (non-allocation of machinery) S2	Big	Limiting working hours per day- Reducing the activity of noisy and polluting machinery in neighbors rest time- Guarantee to remove any damage and satisfy them	Risk Reduction and control

[1] - Consequence
[2] - POF: Probability of Failure

For risk management we should improve reliability of activities by eliminating potential failure modes. To improve reliability of activities, Design Analysis Method such as failure factors analysis can be used. Another way to reduce losses from failure is through reducing the rate of failure events. This reliability is achieved because it identifies potential failure modes as much as possible and evaluates their effects on the efficiency of system. Here, the goal of analyzing the critical factors of failure is to determine specified critical area that can reduce the probability of failure. In this case, potential failures and points of weaknesses are considered and by means of limited resources, their reliability improvement is studied

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