

A Study on Effects of Risk Management in Urban Tunnel Constructing Projects

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Abstract

Although many studies have been conducted on project management and risk management until now, tunnel constructing projects are not under risk management studies. The focus of this study is to define the risks which are effective on tunnel constructing projects and also the method of configuration, relationships and amount of such risks. Then, the responses of the project and the methods of risk management in tunnel constructing projects will be discussed in this study; in order to get favorite results of project through conducting risk management routines.

Tunneling projects consist of complicated events and sophisticated technical systems. So, the risk management must of high importance for managers and engineers involved in such projects. In order to understand the involved risks, some questionings were conducted on tunnel constructing companies. At the end of these questionings, some solutions were proposed to solve the risk problem. In this study, the projects involved in Tehran subway system's construction were studied.

Based on the Standish Group's report, 40 percent of construction projects don't come to end and 50 percent of construction projects consume more budget than estimated. Furthermore, about 50 percent of finished projects don't have the enough functionality. Since covering the most aims and missions of organizations are depicted in operational projects, management and risk control play a vital role in success of projects.

Keywords: urban tunnel, risk management, subway

1. Introduction

Nowadays, risk analysis and management subjects are increasingly involved in decision making process for comprehensive underground projects. Underground construction works and tunneling are under risk in all aspects of the project. During a worldwide study on tunneling projects, clients proposed inappropriate management as the only reason for about 30-50 percent of increase in construction time and expenses. There are also numerous examples on technical failures of tunneling projects.

Feasibility study, contracts and tenders are also subjected to variety of risks which could be categorized as below www.standishgroup.com:

- Financial risks such as high expenses or low rate of return on investment
- Risks that are not acceptable for public facilities
- Ground characteristics change such as geological or geotechnical phenomena or unpredictable water permeability
- Tunneling machines breakdown, cutting tools breakdown, excavation failure, water leakage and etc.
- Contractual risks such as additional works, time delays and etc. which are because of drilling problems.
- Environmental risks that consist of change in quality of ground water, damage to on ground structures, sound pollution.

Because of adverse consequences of delay in utilization time of projects and low quality of operation tasks, and also due to high amount of investment in such projects and assignment of remarkable part of budget to tunneling issues, conducting project management and specially risk management are highly essential. Therefore in this

study, the risks involved in urban tunneling projects and their relation to different factors will be recognized. In addition, the way of dealing with these risks in a scientific manner will be specified.

2. Methodology

The process of this study is based on two stages (Library and field studies) and finally combining the results of the two stages. The field study is conducted by interviews, questionnaires from managers and conductors of projects and finally conclusion of obtained results. The focus of this stage is on recognizing Tehran subway tunneling projects risks and analyzing these risks.

3. Data Analysis Method

In this research, in order to analyze the obtained results, the corresponding analysis and statistical tests are used to recognize the relationship between risks and occurrence probability, time, cost and quality parameters. Furthermore, the explained method is also used for recognizing the relations between effective factors of project (Client, Contractor and Consultant) in correspondence to PMBOK code.

4. History of Risk Management in Tunneling Projects

Due to increasing tendency to risk management issues in tunneling projects and also extension of project management codes, variety of researches have been conducted in risk management aspect of these projects. Some remarkable researches are South Korea project, Okazaki, et. al. and a process of risk management conducted for a lighting system in Hong Kong.

4.1 Application of Risk Management in Underground Project'S Contracts

In order to establish a risk management system into a tunneling project, the whole procedure of the project from the start of design process to construction process should be considered. The different phases of the explained process could be categorized as below:

4.2 Phase 1- Primary Design Step (Feasibility Study and Hypothetical Design)

In this phase below items should be specified:

- Definition of risk methodology
- Defining accepted risks criteria
- Qualitative assessment of project risks
- Accurate and detailed analysis of special parts which are noteworthy

In this step, the client should prepare a qualitative and quantitative assessment on project related risks, by conducting a risk process, and should record these risks.

4.3 Phase 2- Tender and Contract Negotiation

- Obligatory conditions in tender documents
- Considering the risk analysis in tender assessment
- Contract risk cases

4.4 Phase 3- Construction Stage

- Management of the risk which contractor would encounter
- Management of the risk which client would encounter
- Establishment of a relationship between contractor's risk management team and client's

5. Risk Strategy in this Study

The proposed method for risk strategy in this research is to emphasize on using inner relationships. This procedure could be compared to traditional risk management. In this method, by certainty of recognition and updating and managing the risks and occasional accidents, a good understanding and different ideas about project conducting could be achieved. However, source of this method could be complicated and unclear and as a result, recognizing the risk area should be effective on way of management. Some code have been defined to cover great projects which continue to expand and improve with time. PMBOK 2008 offers some codes in this regard. To be brief, recognizing the risk based on standard model is conducted in an uncertainty state, in this code. In this process, by knowing basic threats and opportunities which are related to strategic goals of project, some primary viewpoints about the passes that create threats and opportunities could be managed.

Duty centers and risk dependent centers which are defined as client, contractor and consultant, in different layers,

determine a certain hierarchy that consists of development and layer by layer expansion of related risks.

5.1 Questionnaire Content

Questionnaire introduction based on PMBOK 2013 code, proposes some questions on probability and effectiveness of risks on cost, time qualitative factors of the projects. The recognized risks consist of 16 items. These 16 items consist of political, social, financial, judicial, environmental, natural disasters, losses and damages, contractual, investment, human resource, management, design and construction, programming, material resource, timing program and commitment and warranty risks. The questionnaire form could be find attached.

5.2 Data Analysis

adequacy of sample volume assessment: To estimate the reliability of collected questionnaires, the amount of the reliability is extracted and calculated by Crobaches coefficient [7]. Based on the calculations, this coefficient equals to $\alpha=0.779284$.

6. Effective Layers on Risks

In this part, the results of data analysis conducted by SAS software are introduced. The results of analysis on questionnaires are collected and categorized as below.

Table 1. The results of response plentitude percentage, for occurrence possibility of risks

Occurrence possibility Risk type	Very high	High	Average	Low	Very low
Material resource risk	18.18	20.83	42.80	17.05	1.14
Contract risk	18.87	22.26	42.64	16.23	0.00
Risk of losses and damages	18.25	22.43	41.83	13.69	3.80
Risk of design and construction	17.29	20.30	44.36	17.67	0.38
Financial risk	22.64	22.26	40.75	13.98	0.38
Environmental risk	16.17	18.05	46.99	16.92	1.88
Commitment and warranty risk	18.63	20.91	44.87	15.59	0.00
Human resource risk	16.54	20.68	43.98	17.29	1.50
Investment risk	18.92	21.62	42.47	15.44	1.54
Juridical risk	15.77	22.31	41.92	16.69	3.08
Management risk	16.41	23.28	44.27	16.03	0.00
Natural disaster risk	16.03	18.70	43.51	19.08	2.67
Programming risk	16.98	21.89	41.89	19.25	0.00
Political risk	17.88	21.17	38.69	16.42	5.84
Social risk	15.91	19.32	43.18	17.42	4.17
Timing program risk	18.56	21.59	41.67	18.18	0.00

Table 2. The results of response plentitude percentage, for the effect of time factor

The effect of time factor	Delay time more than 20% of contract time	Delay time of 10-20% of contract time	Delay time of 5-10% of contract time	Delay time less than 5% of contract time	Negligible delay
Risk type					
Material resource risk	11.06	19.47	46.64	19.47	3.54
Contract risk	14.91	21.05	47.37	16.67	0.00

Risk of losses and damages	9.33	16.89	45.78	21.78	6.22
Risk of design and construction	11.84	19.74	47.37	20.61	0.44
Financial risk	16.74	22.03	46.26	14.98	0.00
Environmental risk	11.40	20.18	50.00	15.79	2.63
Commitment and warranty risk	10.22	18.22	53.38	18.22	0.00
Human resource risk	9.65	19.30	47.81	17.98	5.26
Investment risk	16.74	17.19	47.51	18.55	0.00
Juridical risk	9.01	19.37	50.45	16.22	4.95
Management risk	11.61	19.64	48.21	20.54	0.00
Natural disaster risk	12.5	16.98	49.55	15.18	5.80
Programming risk	15.42	17.18	47.14	19.38	0.88
Political risk	14.04	21.05	46.05	17.54	1.32
Social risk	9.73	19.47	48.23	19.03	3.54
Timing program risk	13.72	19.03	48.67	18.14	0.44

Table . The results of response plentitude percentage, for the effect of expense factor

The effect of expense factor	Increasing the cost, higher than 40% of contract cost	Increasing the cost, 20-40% of contract cost	Increasing the cost, 10-20% of contract cost	Increasing the cost, less than 10% of contract cost	Negligible increase
Risk type					
Material resource risk	17.99	20.63	21.69	23.81	15.87
Contract risk	22.63	23.68	25.79	15.26	12.63
Risk of losses and damages	18.09	17.55	22.34	25.53	16.49
Risk of design and construction	17.89	21.05	24.74	22.63	13.68
Financial risk	25.93	23.81	22.75	14.29	13.23
Environmental risk	19.47	20.53	25.79	17.37	16.84
Commitment and warranty risk	20.86	21.39	23.53	18.18	16.04
Human resource risk	17.89	20.53	24.21	18.42	18.95
Investment risk	25.95	19.46	22.16	17.84	14.59
Juridical risk	17.93	23.37	24.46	19.02	15.22
Management risk	18.72	20.86	29.41	18.72	12.30
Natural disaster risk	20.21	19.15	24.47	16.49	19.68
Programming risk	20.63	21.16	23.81	20.63	13.76
Political risk	18.95	27.89	20.53	18.42	14.21
Social risk	18.09	20.21	24.47	20.74	16.49
Timing program risk	19.15	24.47	22.87	20.21	13.30

Table 4. The results of response plentitude percentage, for the effect of Quality factor

The effect of quality factor	Quality: unusable	Quality: confirmable client	not by client	Quality: needs to be confirmed by client	Quality: low quality losses	Negligible quality loss
Risk type						
Material resource risk	0.00	2.65		15.23	41.06	41.06
Contract risk	0.66	0.00		11.84	47.37	40.13
Risk of losses and damages	0.00	0.00		11.33	42.67	46.00
Risk of design and construction	0.66	0.00		11.18	47.37	40.79
Financial risk	0.66	0.00		10.60	42.38	46.36
Environmental risk	0.66	0.00		9.21	44.74	45.39
Commitment and warranty risk	0.00	0.00		10.67	44.00	45.33
Human resource risk	0.00	0.00		13.16	44.08	42.76
Investment risk	0.67	0.00		12.08	46.31	40.94
Juridical risk	0.00	0.00		9.59	47.26	43.15
Management risk	0.00	0.67		13.33	44.00	42.00
Natural disaster risk	0.67	0.00		11.33	42.00	46.00
Programming risk	0.66	0.00		9.93	47.68	41.72
Political risk	1.97	0.00		12.50	44.74	40.79
Social risk	0.00	0.00		9.27	45,03	45.70
Timing program risk	0.00	2.65		15.23	41.06	41.06

7. Correspondence Analysis

After realizing the situation of parameters and making an independence hypothesis, this hypothesis will be evaluated by Correspondence Analysis. Furthermore, by using the above analysis, the relationship between defined risks and effective layers (factors affected by risks are client, consultant and contractor) will be studied. In this study, each person has produced 16 observations to risks and 4228 observations are produced. Since 2405 number of these observations possess missing data and are eliminated, eventually 1823 number of observations have been calculated (n=1823).

7.1 Correspondence Analysis for Occurrence Probability

This analysis has three variables for occurrence probability; first variable is ranged from low occurrence probabilities to very high occurrence probabilities and for the second variable the 16 risks is considered. Eventually, the calculations result in the following charts and figures:

Decomposition of K2 and inertia				
Exclusive quantity	Inertia	K2	percentage	Accumulative percent
0.13784	0.019	80.3273	81.52	81.52
0.05315	0.00282	11.944	12.12	93.64
0.02925	0.00086	3.617	3.67	97.31
0.02503	0.00063	2.6491	2.69	100
total	0.02331	98.5374	100	
Degree of freedom=60				

Row coordinate		
	First component coordinate	Second component coordinate
Very low	1.0608	0.0199
Low	-0.0068	-0.0762
Average	-0.0164	-0.0259
High	-0.0181	0.0432
Very high	-0.0315	0.0813

Column coordinate		
	First component coordinate	Second component coordinate
Material resource risk	-0.0408	-0.0013
Contract risk	-0.1312	0.0291
Risk of losses and damages	0.1649	0.0756
Risk of design and construction	-0.0988	-0.0386
Financial risk	-0.1074	0.1298
Environmental risk	0.0197	-0.0706
Commitment and warranty risk	-0.01312	0.0128
Human resource risk	-0.0101	-0.0356
Investment risk	-0.0110	0.0425
Juridical risk	0.1132	-0.0129
Management risk	-0.1287	-0.0054
Natural disaster risk	0.0832	-0.0784
Programming risk	-0.1269	-0.0425
Political risk	0.3266	0.0434
Social risk	0.1989	-0.0443
Timing program risk	-0.1294	-0.0044

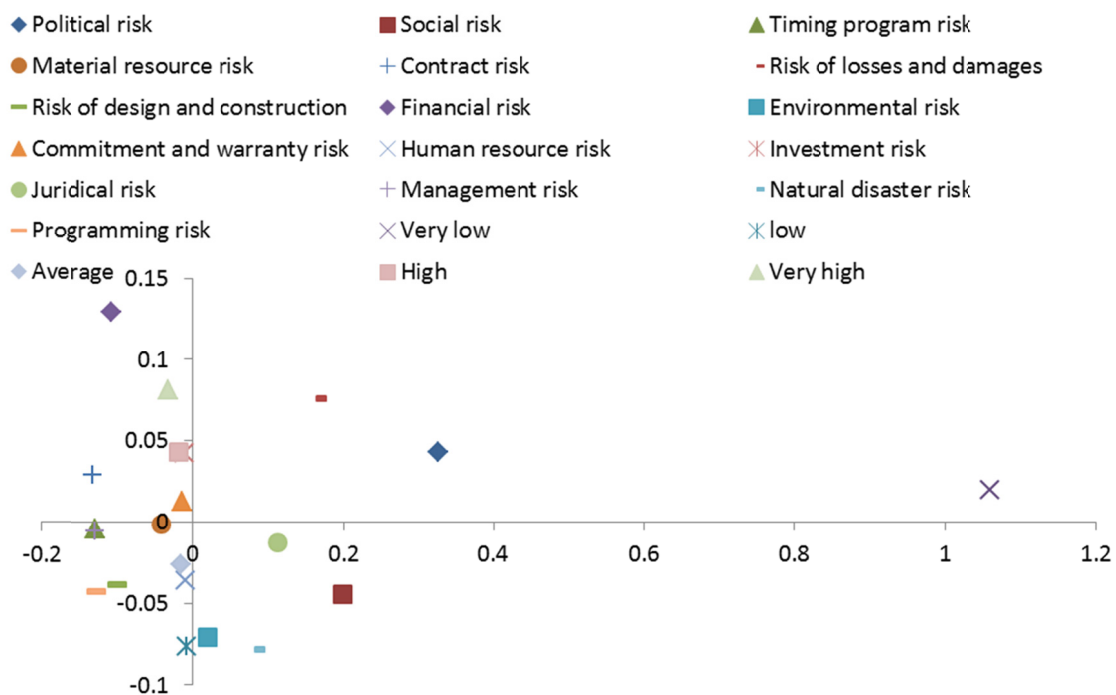


Figure 1. Correspondence Analysis of occurrence probability of risks

In the Correspondence Analysis of occurrence probability of different risks chart (Fig. 1), it is shown that the first component (Horizontal axis) consists of 81.52 percent of data. The very low occurrence probability has the highest value on this axis. In other words this value is the basic reason for the formation of first component. The rest of values for occurrence probabilities and related risks are mostly are scattered around the center. This demonstrates the independence of very low occurrence probabilities from defined risks, since there is no risk value in vicinity of this number). It also demonstrates the independence of other occurrence probabilities values from risk titles, since these values and risk titles are concentrated around the center without any regularity. This independence validates the hypothesis on the independence between occurrence probabilities and risk titles which was explained before.

7.2 Correspondence Analysis for Time Parameter

This analysis has two variable for time parameter too; first variable is ranged from negligible delay to Delay time more than 20% of contract time and for the second variable the 16 risks is considered. Eventually, the calculations result in the following charts and figures:

Decomposition of K2 and inertia				
Exclusive quantity	Original inertia	K2	percentage	Accumulative percentage
0.16205	0.02626	94.876	80.32	80.32
0.05818	0.00339	12.23	10.35	90.67
0.04501	0.0023	7.32	6.2	96.87
0.03201	0.00102	3.701	3.13	100
Total	0.0327	118.127	100	
Degree of freedom=60				

	Row coordinate	
	First component coordinate	Second component coordinate
Negligible delay	1.0328	0.1082
Delay time less than 5% of contract time	0.0036	-0.0774
Delay time 5-10% of contract time	0.0017	-0.012
Delay time 10-20% of contract time	-0.0288	0.0098
Delay time more than 20% of contract time	-0.1497	0.1257

	Column coordinate	
	First component coordinate	Second component coordinate
Material resource risk	0.0980	-0.0170
Contract risk	-0.1666	0.0384
Risk of losses and damages	0.2899	-0.0382
Risk of design and construction	-0.1070	-0.0754
Financial risk	-0.1857	0.1043
Environmental risk	0.0352	.0163
Commitment and warranty risk	-.1172	-0.1007
Human resource risk	0.2210	0.0012
Investment risk	-0.1762	0.0461

Juridical risk	0.2070	-0.0002
Management risk	-0.1326	-0.0886
Natural disaster risk	0.2328	0.1026
Programming risk	-.1076	0.0235
Political risk	-0.0745	0.0350
Social risk	0.1103	-0.0435
Timing program risk	-0.1233	-0.0049

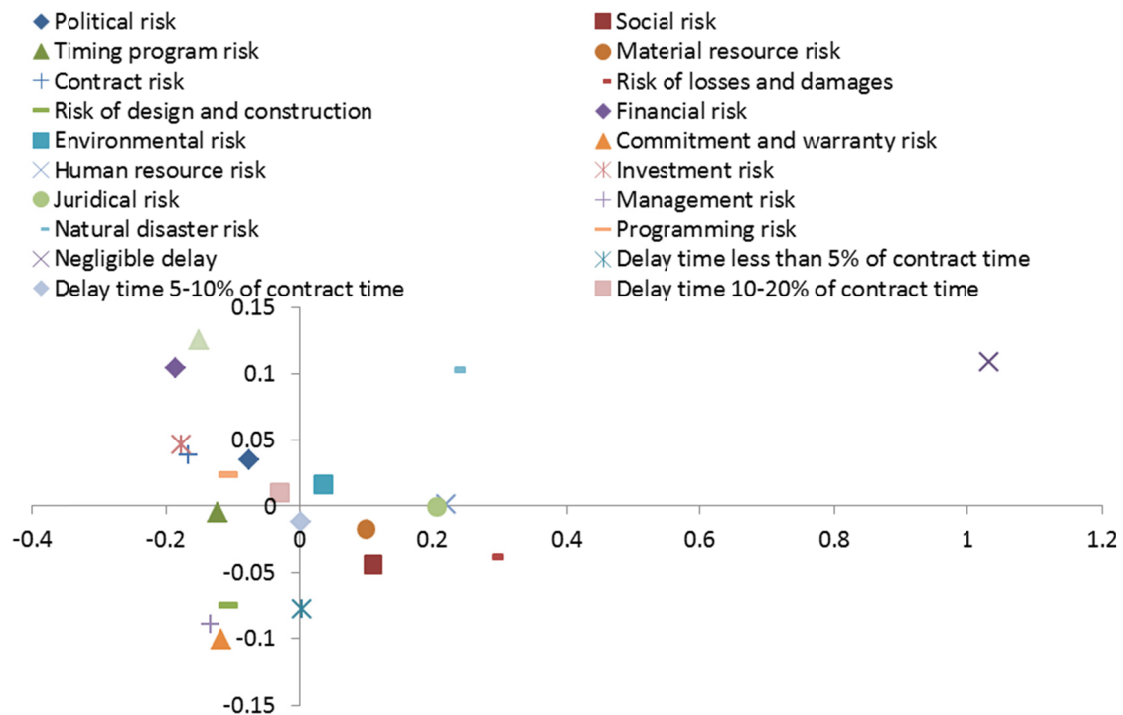


Figure 2. Correspondence Analysis of time and risks

By investigating the figure of time parameter, the occurrence probabilities will be resulted. In other words, the first component (Horizontal axis) consists of 80.32 percent of data. The negligible delay has the highest value on this axis. In other words this value is the basic reason for the formation of first component. The rest of values for time and related risks are mostly scattered around the center. This demonstrates the independence of negligible delay from defined risks. It also demonstrates the independence of other time values from risk titles.

7.3 Correspondence Analysis for Expense Parameter

This analysis has two variable for time parameter too; first variable is ranged from Negligible expense increase to Increasing the cost, higher than 40% of contract cost and for the second variable the 16 risks is considered. Eventually, the calculations result in the following charts and figures:

Decomposition of K2 and inertia				
Exclusive quantity	Original inertia	K2	percentage	Accumulative percentage
0.08408	0.00707	21.2913	47.45	47.45
0.05929	0.00352	10.5892	23.60	71.04
0.04696	0.00220	6.6413	14.80	85.84

0.04593	0.00211	6.3532	14.16	100.00
جمع كل	0.01490	44.8750	100.00	
Degree of freedom=60				
Row coordinate				
	First component		Second component	
	coordinate		coordinate	
Negligible increase	0.0633		0.1031	
Increasing the cost, less than 10% of contract cost	0.1341		-0.0509	
Increasing the cost, 10-20% of contract cost	-0.0050		0.0157	
Increasing the cost, 20-40% of contract cost	-0.0620		-0.0730	
Increasing the cost, higher than 40% of contract cost	-0.1040		0.0307	

Column coordinate		
	First component coordinate	Second component coordinate
Material resource risk	0.1118	-0.0322
Contract risk	-0.1312	-0.0178
Risk of losses and damages	0.1651	0.0039
Risk of design and construction	0.0729	-0.0577
Financial risk	-0.01822	0.0084
Environmental risk	-0.0036	0.0599
Commitment and warranty risk	-0.0188	0.0295
Human resource risk	0.0495	0.0751
Investment risk	-0.0830	0.0538
Juridical risk	0.0094	-0.0291
Management risk	-0.0115	-0.0291
Natural disaster risk	0.0055	0.1341
Programming risk	0.0074	-0.0290
Political risk	-0.0513	-0.1024
Social risk	0.0679	0.0179
Timing program risk	-0.0082	-0.0842

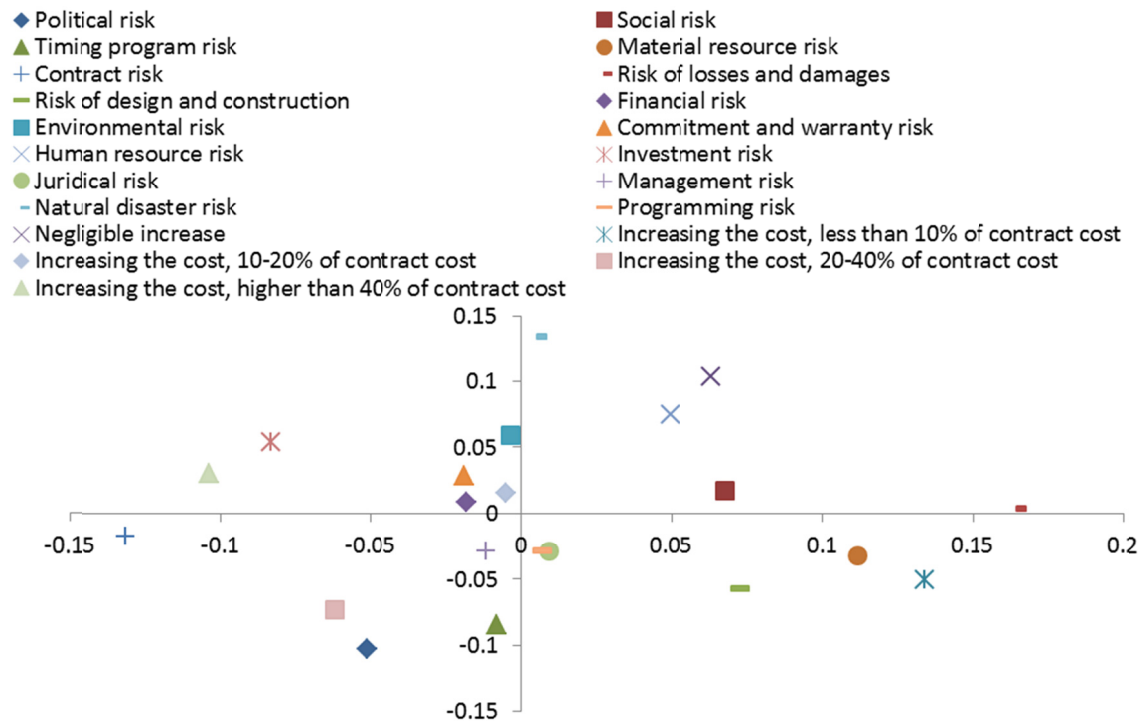


Figure 3. Correspondence Analysis of expense and risks

As the chart of expense parameter demonstrates, the state of aggregation around center is present like other parameters discussed formerly but with higher scattering (Fig. 3). This could validate the uniform distribution theory, however important results could be excluded from this chart. The relation between Increasing the cost, higher than 40% of contract cost and financial and investment risks could be realized.

7.4 Correspondence Analysis for Quality Parameter

This analysis has two variable for quality parameter too; first variable is ranged from Negligible quality loss to unusable quality and for the second variable the 16 risks is considered. Eventually, the calculations result in the following charts and figures:

Decomposition of K2 and inertia				
Exclusive quantity	Original inertia	K2	percentage	Accumulative percentage
0.14915	0.02225	53.6138	71.02	71.02
0.0752	0.00565	13.627	18.05	89.07
0.04589	0.00211	5.0756	6.72	95.8
0.03628	0.00132	3.1724	4.2	100
Total	0.03132	75.4888	100	
Degree of freedom=60				

	Row coordinate	
	First component coordinate	Second component coordinate
Negligible quality loss	-0.0134	-0.0305
Quality: low quality losses	-0.0223	0.0011
Quality: needs to be confirmed by client	0.0939	0.0658
Quality: not confirmable by client	3.1235	0.1378
Quality: unusable	-0.3842	1.0156

Column coordinate	First component coordinate	Second component coordinate
Material resource risk	0.5523	0.0216
Contract risk	-0.0493	0.037
Risk of losses and damages	-0.0338	-0.0808
Risk of design and construction	-0.054	0.0286
Financial risk	-0.0554	0.0007
Environmental risk	-0.0667	-0.0087
Commitment and warranty risk	-0.0394	-0.0838
Human resource risk	-0.0215	-0.0515
Investment risk	-0.0473	0.0374
Juridical risk	-0.0491	-0.0838
Management risk	0.12	-0.0347
Natural disaster risk	-0.05	0.0091
Programming risk	-0.0633	0.0145
Political risk	-0.0757	0.2174
Social risk	-0.05	-0.0973
Timing program risk	-0.0173	0.0685

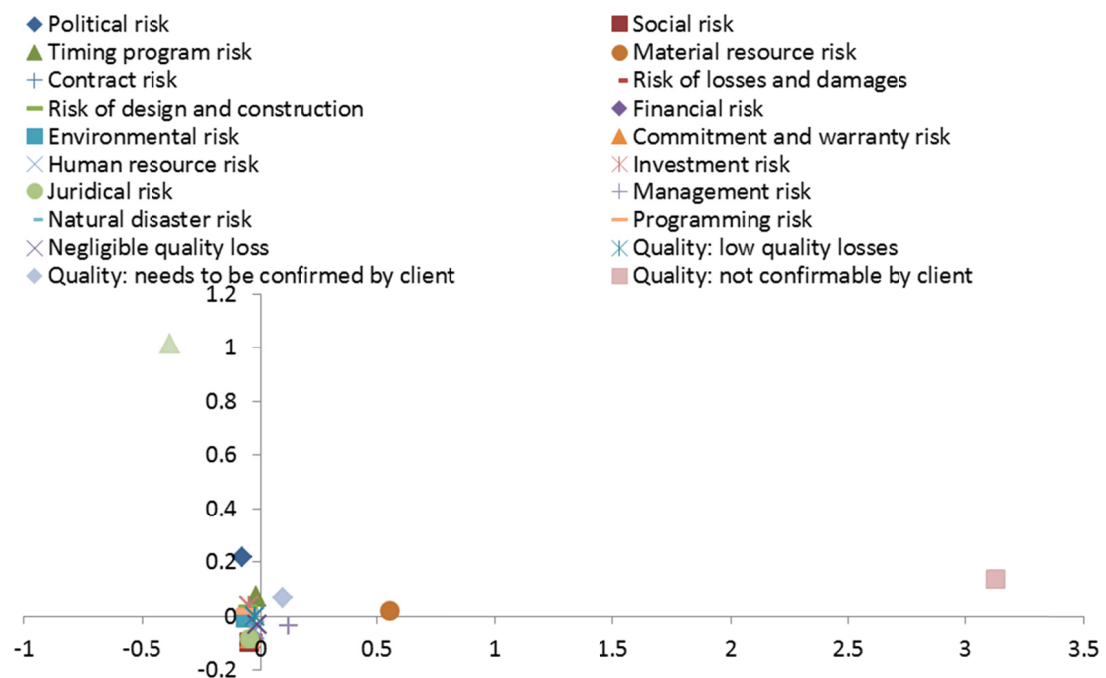


Figure 4. Correspondence Analysis of quality and risks

By considering quality and risks chart (Fig. 4), the obtained results are somehow the same as former analysis stages, but in this chart unconfirmed qualities and unusable qualities are far from risk titles. The rest of values are concentrated around center along with risk titles.

7.5 Correspondence Analysis on Effective Layers

Decomposition of K2 and inertia				
Exclusive quantity	Original inertia	K2	percentage	Accumulative percentage
0.3328	0.11075	201.905	58.34	58.34
0.25578	0.06542	119.266	34.46	92.79
0.11693	0.01367	24.924	7.2	100
0.00285	0.00001	0.015	0	100
Total	0.18986	346.11	100	
Degree of freedom=75				

Row coordinate		
	First component coordinate	Second component coordinate
Consultant	0.243	0.986
Contractor	-0.1902	0.0231
Client	0.5834	-0.0947
Absence of consultant	-0.048	-0.1922
Absence of contractor	0.6002	-0.0697
Absence of client	-0.3535	0.0567

Column coordinate		
	First component coordinate	Second component coordinate
Material resource risk	-0.2805	0.2117
Contract risk	0.3647	0.0017
Risk of losses and damages	-0.3001	-0.2067
Risk of design and construction	0.1191	0.8504
Financial risk	-0.2185	-0.0486
Environmental risk	-0.4522	-0.1291
Commitment and warranty risk	0.1952	-0.2148
Human resource risk	-0.3551	-0.0235
Investment risk	0.6141	-0.2873
Juridical risk	0.4842	0.0221
Management risk	-0.0629	0.0591
Natural disaster risk	-0.3725	-0.1488
Programming risk	-0.0305	0.0847
Political risk	0.4836	-0.0954
Social risk	-0.1713	-0.1834
Timing program risk	-0.1462	0.1066

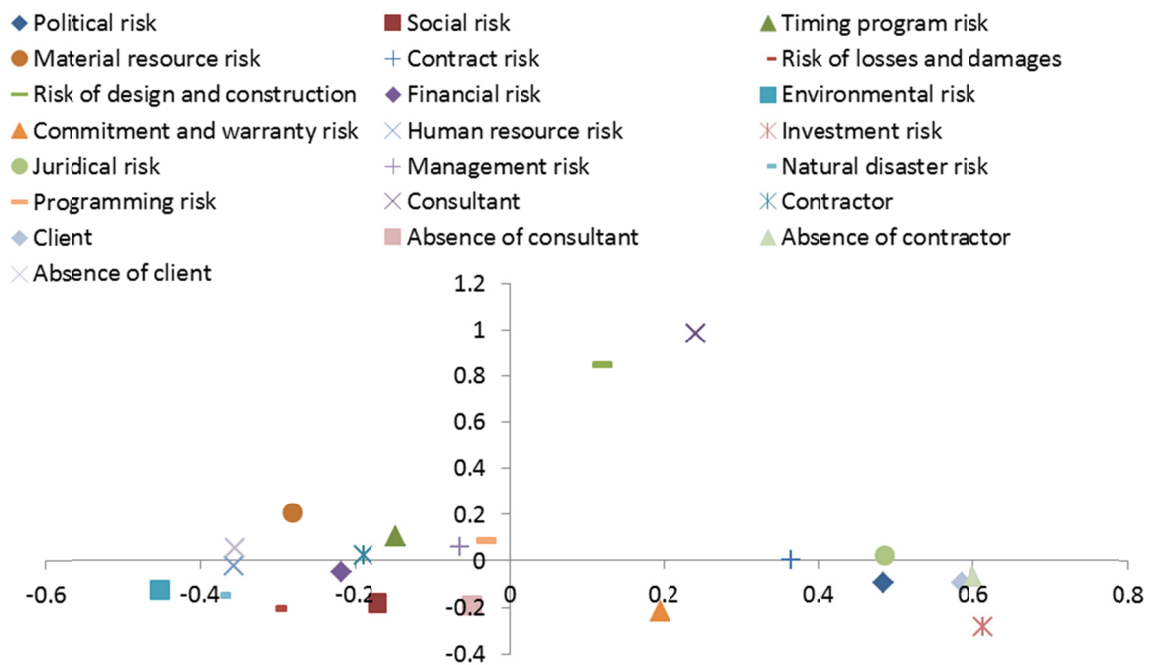


Figure 5. Correspondence Analysis of effective factors and risks

As it is shown in the chart, client is the effective factor among values on second component (Fig. 5). Furthermore, client and contractor factors could be related to each other, since the presence of client results in absence of contractor for the same risk. Also, investment, judicial and political risks are highly effective on client's affected layer. The financial risk is the effective risk on contractor. Although concentration of most risks (specially contractor factor) is around center, this could be supposed as the independence sign of effectiveness of risks. As mentioned before, the relation between financial and investment risks with 5th value of expense (Increasing the cost, higher than 40% of contract cost) is sensible.

Eventually the following categorization could be concluded:

- Effective risks on client: judicial risks, Investment risks, Political risks
- Effective risks on contractor: Financial risks, Social risks, programming risks, Contractual risks, Human resource risks, Timing program risks, Environmental risks, Material resource risks, Management risks, Natural disaster risks, Commitment and warranty risks, Risks of losses and damages

8. Conclusion

In this research, the effect of different factors of recognized risks on different parameters, i.e. occurrence probability, quality, construction time, cost of project, were studied using corresponding analysis (based on PMBOK proposed items). In each analysis, the obtained results were demonstrated graphically. The results obtained from graphical charts of corresponding analysis show the relationship between risks and their parameters. The interpretation of results based on corresponding analysis, gives a perfect and adequate understanding about important risks and relationship between risks. This understanding could be used while decision making process and for suitable leadership of project. In the next stage, project manager could evaluate different risk qualification methods and by using the results of this research the one could chose the different methods of dealing with risks such as avoidance, decrease, acceptance and transmission.

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