Modern Applied Science; Vol. 10, No. 12; 2016
ISSN 1913-1844 E-ISSN 1913-1852
Published by Canadian Center of Science and Education

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

Mehdi Mahdavi[1] & Mehrdad Kangani[1]

[1] Engineering Faculty, Islamic Azad University of Shoushtar, Shoushtar, Iran

Correspondence: Mehdi Mahdavi, Engineering Faculty, Islamic Azad University of Shoushtar, Shoushtar, Iran. E-mail: esfehani.mohamad3@gmail.com

Received: June 7, 2016 Accepted: June 28, 2016 Online Published: July 11, 2016

doi:10.5539/mas.v10n12p34 URL: http://dx.doi.org/10.5539/mas.v10n12p34

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.

## 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 $\propto$=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<br>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 10-20% of contract time | Delay time 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: not confirmable 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 |

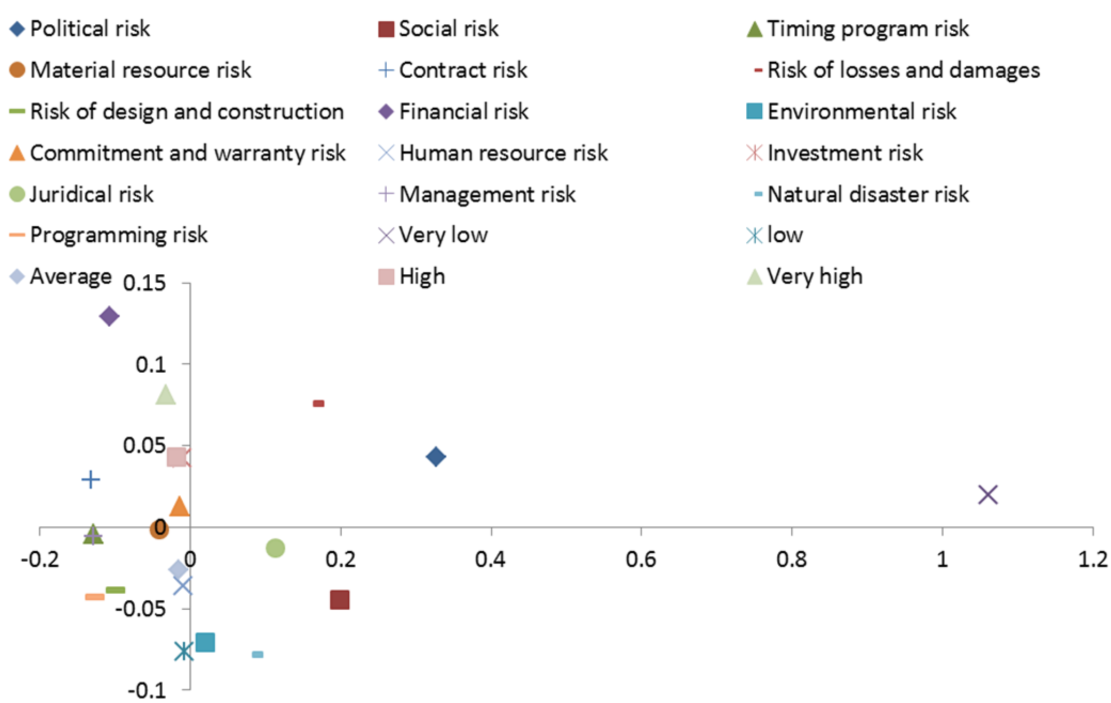


Figure 1. Correspondence Analysis of occurrence probability of risks

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 |

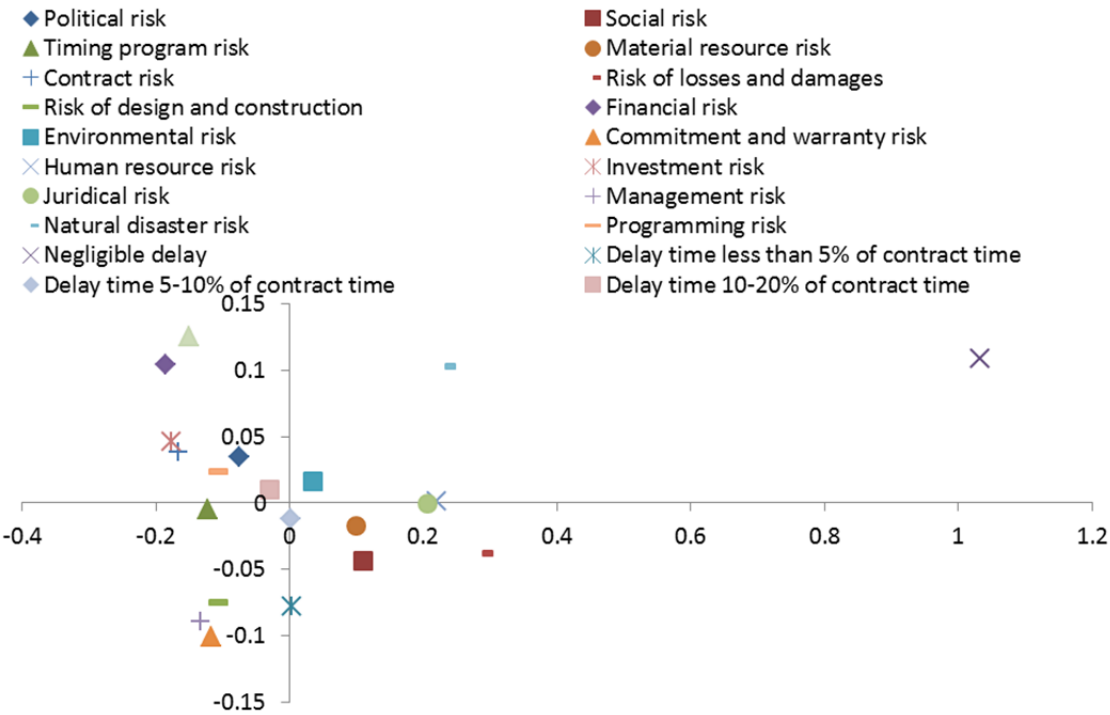


Figure 2. Correspondence Analysis of time and risks

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 کل | 0.01490 | 44.8750 | 100.00 | |

Degree of freedom=60

| Row coordinate | | |
|---|---|---|
| | First component coordinate | Second component 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 |

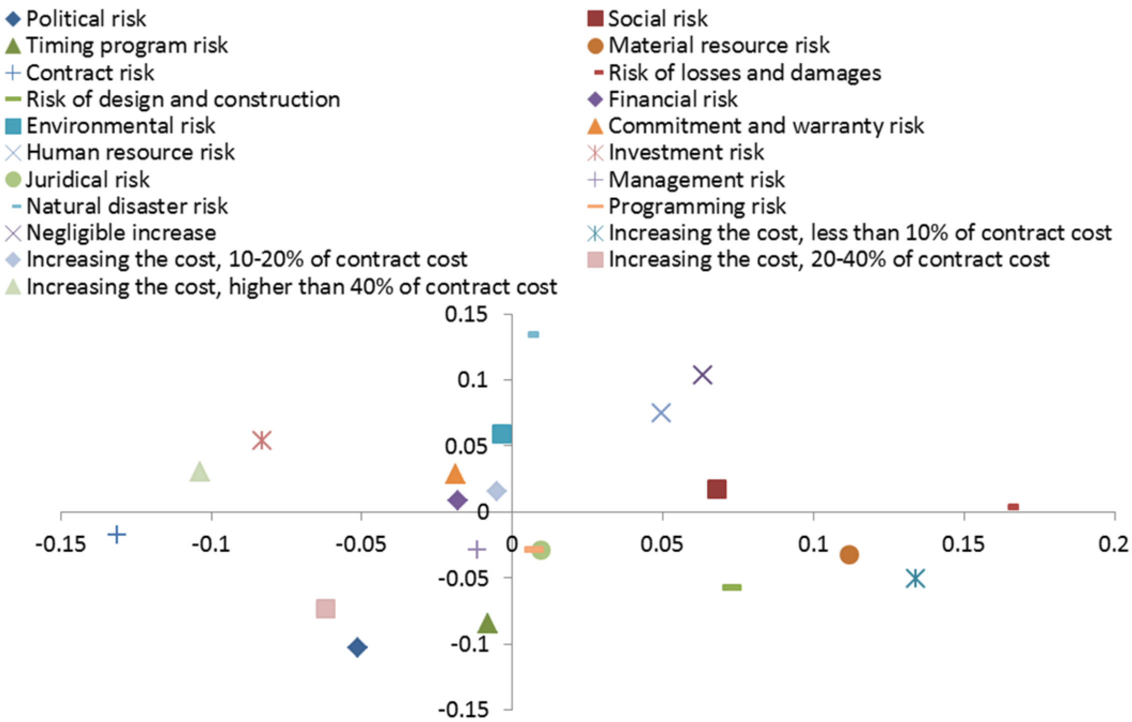


Figure 3. Correspondence Analysis of expense and risks

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 |

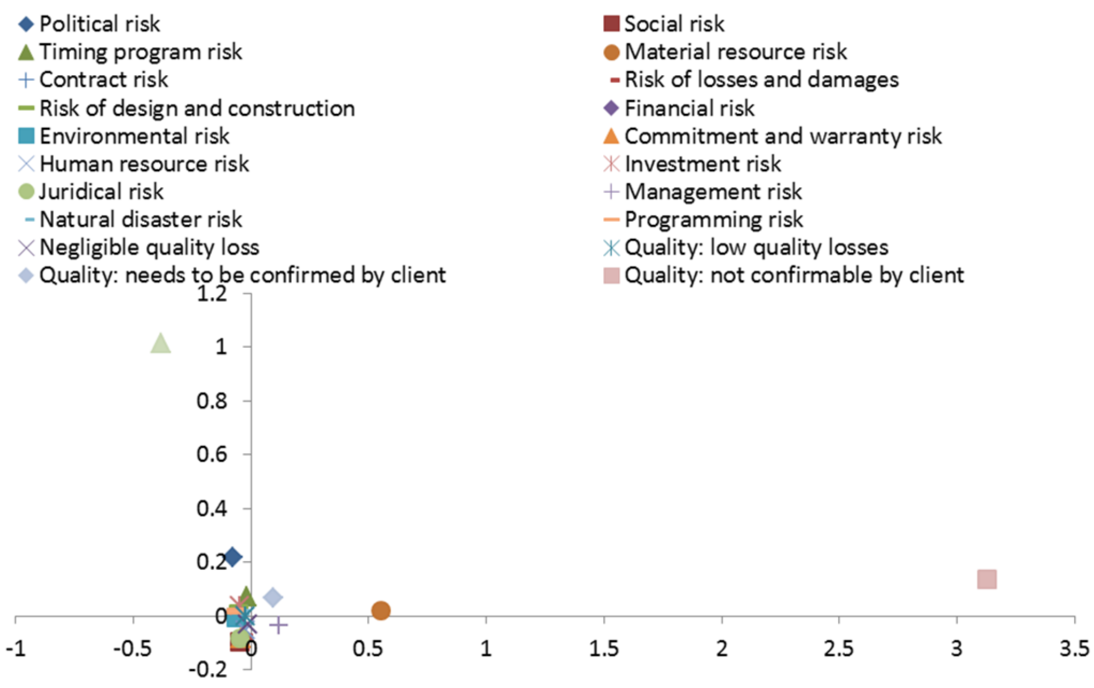


Figure 4. Correspondence Analysis of quality and risks

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 |

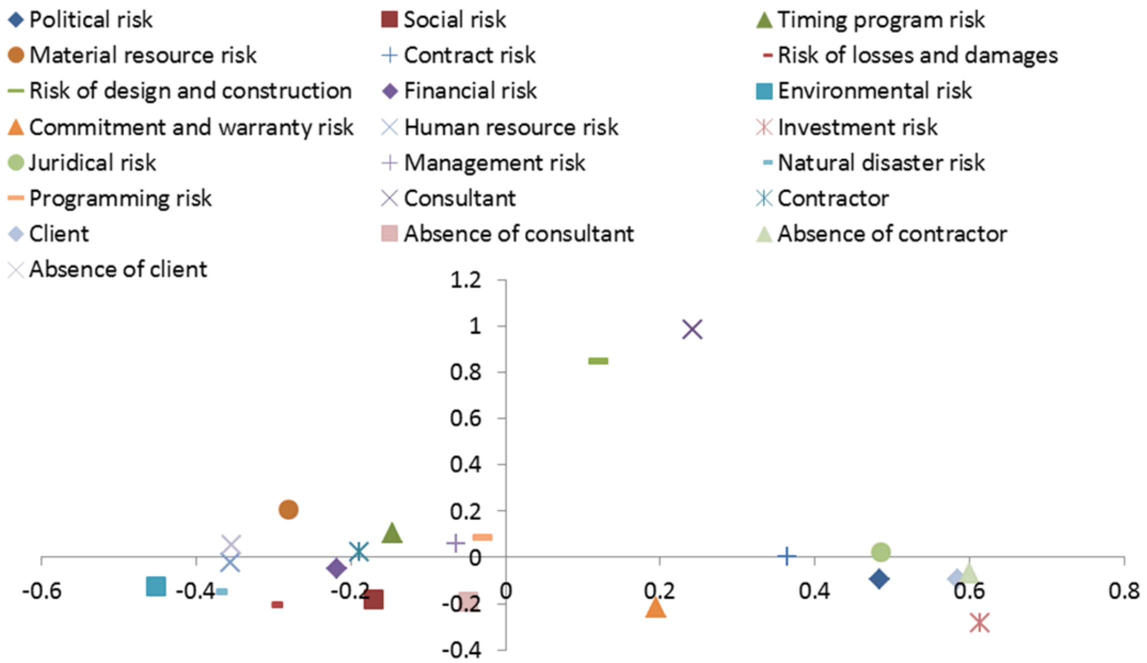


Figure 5. Correspondence Analysis of effective factors and risks

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 5$^{th}$ 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.

## References

Alipourian (1384). *Applied rock mechanic.* Amirkabir Publication

Cronbach, L. J. (1951). Coefficient Alpha and the Internal Structure of Tests. *Psychometrika, 16*, 297 - 334.

FAA. (2007). *System Safety Handbook.* Retrieved from http://www.asy.faa.gov/Risk/SSHandbook/Chap12007.pdf

Greenacre, M. J. (1989). The Carroll-Green-Schaffer Scaling in correspondenceAnalysis: A Theoretical and Empirical Appraisal. *Journal of Market Research, 26*, 358 - 365.

Greenacre, M. J. (1994). Multiple and Joint correspondence Analysis. in Greenacre, M.J. and Blasius, J. (Ed) correspondence Analysis in the Social Sciences, London: Academic Press.

Ng, M. F., & Rao, V. M. (2003). Tummala and Richard C. M. Yam, Engineering Department, Rome 3 (cps) company limited, NT, Hong kong. A risk – based main tenance management modal for toll road / tunnel operations. Construction Management and Economics.

Risk management for the new tunnel:ny construction using other tunnel records and helicopter borne survey in accretionary complex, k. okazaki, etal, tunneling and under quound space technology, 21(2006), 244.

Risk Management Practices (2006). A contractor's perspective, woong suk yoo, president, ske & c president, korea, I TA-AITES world Tunnel congress 2006 & 32 nd General Assembly, seoul, Korea.