Developing a Theoretical Framework for Implementation of Risk Management Process in Iranian Construction Projects

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ABSTRACT

Comprehensive research studies have been conducted in recent years, specifically about risk management in construction projects, resulting in establishing methods of risk management with improved performance and efficiencies, benefitting for the companies and industries. However, there are still lacks in this area. Lack of enough knowledge about the structured methods of risk management is still significant, preventing the methods from being widely employed.

This master thesis is a research carried out on steel-framed structure buildings in Iranian construction projects, investigating the risk management methods in five different stages of the construction, which are earthwork, reinforcement, formwork, concrete work and steel structure. Perception and employment methods of risk management have been studied in the mentioned stages, which has been done through questionnaire surveys and checklists. To do so, 35 members of top Iranian construction companies were chosen and asked to participate in the survey, where 20 of them participated and answered the questionnaires and checklists and as a result, response rate was found to be 57.1%.

To develop the risk identification efficiently, Risk Breakdown Structure was also employed. These methods were selected to be done among a certain number of construction companies.

To assess the likelihood of risks occurrence, and their impact on projects objectives, qualitative analysis method was implemented through probability and impact matrix. The assessments were done separately on each objective, i.e. time, cost, quality, and health and safety, resulting in determination of 30 main risks.

An explicit result of the survey was the unfamiliarity of the Iranian construction companies with the formal methods of risk management. It was found that most of the companies are still dependent on the previous experiences, checklist and brainstorming methods and consultations to identify the potential risks and face with them. This unfamiliarity which could be due to lack of education, has been focused in this research and in fact, in this study, it has been tried to develop responding techniques to the potential risks, which have been identified as high risks, in order to have more efficient risk management.

Keywords: Iranian construction industry, steel structure buildings, qualitative method, risk management, risk management process

ÖZ

Son yıllarda, özellikle inşaat projelerindeki risk yönetimi alanında, endüstri ve şirketler için yarar sağlayabilecek ve daha etkili ve gelişmiş bir performansla sonuçlanacak risk yönetimi metotları geliştiren kapsamlı araştırmalar yapılmıştır. Ancak, bu alanda yapılan araştırmalar yetersiz bulunmaktadır. Risk yönetiminin metotları ile ilgili bilgi eksikliği, bu metotların geniş alanlarda uygulanmasını engelleyerek önemli bir sorun haline gelmiştir.

Bu yüksek lisans tezindeki araştırma, İran inşaat projelerinin çelik yapılı binaları üzerine gerçekleştirilmiştir. Araştırma, inşaatın toprak çalışması, demir donatı, kalıp, beton işi ve çelik yapı gibi beş farklı sürecindeki risk yönetimi metotlarını araştırmaktadır. Adı geçen süreçlerdeki risk yönetimi metotlarının algısı ve kullanımı, anket ve kontrol listesi kullanılarak araştırılmıştır.

Risk tanımlamayı etkili bir şekilde geliştirmek için Risk Çözümleme Yapısı da kullanılmıştır. Bu metotlar, belirlenen bir sayıdaki şirketlerde kullanılmak için seçilmiştir.

Risk oluşum olasılıklarını ve proje amaçları üzerindeki etkilerini değerlendirebilmek adına nitel metotlar, olasılık ve etki tablosu ile uygulanmıştır. Süre, maliyet, kalite, sağlık ve güvenlik gibi belirlenen 30 temel için ayrı değerlendirmeler yapılmıştır.

Risk yönetiminin resmi metotlarının, İran inşaat şirketleri tarafından bilinmemesi anketlerin belirgin sonuçlarından birini oluşturmaktadır. Olası risklerin tanımlanması ve alınacak olan önlemlerin belirlenmesi için şirketlerin hala eski deneyimleri, kontrol listeleri, beyin fırtınası yöntemleri ve danışmanlıklara bağımlı oldukları sonucuna varılmıştır. Metotların bilinmemesinin, eğitim eksikliğinden kaynaklandığı düşünülmüştür ve bu konu araştırmanın odak noktalarından biri haline gelmiştir. Ayrıca bu çalışmada, yüksek risk olarak tanımlanan olası riskler karşısında, daha etkili bir risk yönetimi geliştirmek adına, yanıtlamam tekniklerinin geliştirilmesi amaçlanmıştır.

Anahtar Kelimeler: İran inşaat endüstrisi, çelik yapı binaları, nitel metot, risk yönetimi, risk yönetimi süreci

To My Dear Mom & Dad

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LIST OF ABBREVIATIONS

EMV	Expected Monetary Value
HSE	Health and Safety Executive
PIM	Probability and Impact Matrix
PMBOK	Project Management Body of Knowledge
PMI	Project Management Institute
PRM	Project Risk Management
RBS	Risk Breakdown Structure
RC	Risk Category
RE	Risk Event
RM	Risk Management
RMP	Risk Management Process
WBS	Work Breakdown Structure
WSDOT	Washington State Department of Transportation

Chapter 1

INTRODUCTION

1.1 Introduction

This chapter mainly includes the problem explanation and the background information about the thesis topic. A brief explanation of risk, the risk management process, methodology, objectives and finally the achievements are explained in this chapter. Thesis guideline, brought at the end of this chapter is also describing the context of this research work.

1.2 Background Information

Risk management is accepted to be a critical sub-field of project management, especially in construction industry, and as stated by PMBOK (2013), it is one of the top ten critical knowledge areas in every project (Klemetti, 2006).

According to the Project Management Institute (PMI), risk is defined as an event, which although may not happen, if happens, there will be negative or positive impacts on the project objectives. Having this in mind, project risk management (PRM), is focused on minimizing the failure probability of the projects, in reaching their planned aims, as much as possible. By means of risk management, it is aimed to increase the beneficial desirable consequences along with decreasing the adverse, undesirable impacts of the risks on the projects aims.

Different research works have so far reported the benefits of risk management. Smith et al. (2006), have stated about important role of risk management in better understanding the unmanageable threats and preventing from their adverse effects; and

Zou et al. (2007) expressing about the importance of this process in fulfilling the projects' main targets, such as cost, time, quality and etc.

Risk management is known to be as an organized procedure of risks identification, evaluation, responding techniques as well as monitoring and controlling them (PMI, 2008). For each of these stages, there are different known techniques to be performed, depending on factors like project size, complexity and time limitations.

The first stage of risk management, according to PMI (2009), is known as risk identification, in which a list of all potential risks, having both negative and positive impacts, are prepared regularly all the way through the project. Risk identification is definitely known as the very basic and fundamental stage of risk management, and the success (or failure) of the following stages is directly linked to the quality of it (Chapman, 2011).

The next stage after risk identification is called the risk analysis, which aims to determine the impact of risks on the project by means of methods such as qualitative and quantitative techniques. Ranking the identified risks is the outcome of performing this stage, distinguishing the top risks that are required to be responded (Flanagan and Norman 1993; Mulcahy, 2010).

Risk analysis is actually the linkage between risk identification and the next stage, which is actually the regular management of the risks. The later stage is mainly dealing with developing options and techniques to respond and face with the potential risks that are more likely to happen.

Following the risk respond stage, there is monitoring and controlling stage aiming to check and control the risks situations and management process, based on plans and responding techniques (Mulcahy, 2010).

Iran is known to be a developing country with growing opportunities and steady interest growth in construction projects. However, unlike this interest growth, which requires encountering different types of risks and managing them, risk management is not being considered as important as it should be. It is also reported by Smith et al. (2006) that the significance of this process is not so far being understood, and not all the organizations are motivated strongly to employ and benefit from the structured methods of risk management.

This research work is focused on the construction project of steel-framed structure buildings due to their popularity in Iran. The process of risk management was studied in five different activities of construction, including earthwork, reinforcement, formwork, concrete work and steel structure, to investigate the perception and performance of risk management in the construction areas. It is believed that risk management should concentrate on identifying the risks of the work packages and accompanying activities, as well as the overall risk of the project. Moreover, to deal with huge amount of data that is usual in risk management, a very handy method to structure them is to employ methods like Risk Breakdown Structure (RBS). In this study, a combination of Risk Breakdown Structure (RBS) and Work Breakdown Structure (WBS) were used to develop efficient risk identification in steel structure projects. To collect data, checklists and questionnaire surveys were employed, and to evaluate the gathered data, qualitative method was performed by means of probability and impact matrix to determine the occurrence probability and impact of each risk on the project objectives. In the last stage, strategies and responding techniques were developed against various types of identified and evaluated top ranked risks.

1.3 Scope and Objectives

Although many decisions have to be made about the building material, in fact a few factors are influential on those decisions. In other words, the decisions about building materials are dependent on a few factors, such as workers skills, environmental concerns, materials availability, etc. Steel framed building structures are more popular in Iran due to the weather conditions and faster erections. Due to these reasons, steel framed structures were focused in this study.

The main objectives of this research study are listed as following:

- First, to evaluate how the Iranian construction companies perform the risk management practically, specifically in steel-framed structure buildings.
- Second, to identify and categorize the risks associated with the steel-framed structure construction projects, and rank the risks.
- Finally, to provide a theoretical framework, aimed to improve the implementation of risk management in Iranian construction companies.

It is worth explaining that the theoretical framework was including introducing some formal methods of risk management such as utilizing combination of Risk Breakdown Structure (RBS) and Work Breakdown Structure (WBS) methods to develop the risk identification more efficiently as well as it has been tried to develop the suitable formal methods of facing with potential high risks which are commonly occurring in steel-framed structure buildings in Iran and in order to benefit the companies, in performing the formal methods of risk management.

Due to differences between the theory of risk management and the practical performance, these two were compared and their differences and similarities were investigated.

The following list includes the research questions that are answered by performing this research study:

How the risk management methods are being viewed in Iran?

How is the practical employment of risk management process?

What causes the deficiencies of employing risk management process in Iran?

What are the popular employed methods of managing the risks?

What are the main difficulties in performing the risk management process?

1.4 Works Carried Out

In the first step, a literature review including the previous research works was comprehensively performed.

In the second stage, having selected the Iranian steel-framed structure projects, the investigation about performance of risk management in the projects was done in different working stages.

Third step was involved in preparing the questionnaire to determine the familiarity of Iranian construction companies with risk management process and techniques.

In the fourth step, a checklist was prepared (containing 105 different risks) for collecting data and further analyses of the identified risks in various categories, and a Risk Breakdown Structure was developed.

Finally, qualitative analysis was performed on the data by means of probability and impact matrix.

1.5 Achievements

The following points are presenting brief achievement of this research:

- A combination of Risk Breakdown Structure (RBS) and Work Breakdown Structure (WBS) methods was employed to develop the risk identification more efficiently.

- A total number of 30 key risks were identified and determined, affecting the projects objectives by means of qualitative risk analysis; and their impact was determined together with their probability of occurrence.
- According to the analyses, the highly threatening risks affecting the project objectives were; "Inaccurate or incorrect estimation of time, cost and resources in accordance with WBS", which highly impacts time and "Unavailability (lack) or high price of materials due to economic conditions in project region or country" which massively impacts cost. Moreover, "Any change in political situation such as sanction, etc." and "Adjacent structures collapse (Collapse of neighboring buildings) due to inadequate retaining walls" were highly influencing the quality, and health and safety objectives of the project, respectively. Finally, among all the risks, "Inaccurate or incorrect estimation of time, cost and resources in accordance with WBS" had the highest negative influence on the objectives of project overall.
- Based on the results of quantitative analysis, the most important risks with high negative impacts were assigned to the cost risks, followed by time, quality, and health and safety.
- Compared to the developed countries, Iranian construction sector requires employing structured risk management methods, although it is still based on unstructured approaches. For example, in risk identification stage, using past experiences and consulting with partners are still popular among the companies. In fact, intuition, judgment and experiences are the popular management methods, and only few companies were employing known risk management methods like Monte Carlo Simulation and the matrix of probability and impact.
- Regarding the responding methods to the risks, it was found that a large group of studied companies was not familiar with the formal responding methods. In fact, only

a few of the companies indicated that the transfer method of risks responding (to the other parties or insurance companies), helps them to mitigate the impacts of risks. Although it was stated by many of the participants that the occurred risks are manageable, due to lack of knowledge, they are not motivated to employ the structured methods.

- As stated by most of the companies, limited cost and time are main restrictions, preventing risk management methods to be employed.
- A practical method was finally developed for the projects facing with potential high risks, considering cost, time, health and safety and the quality, in order to benefit the companies, contractors and other stakeholders in performing the formal methods of risk management.

1.6 Thesis Guideline and Outline of the Thesis

The thesis outlines cover various sections, starting from introduction, giving general information about the method of risk management, the objectives and aims. Afterwards, literature review chapter provides broad theoretical framework, studied and performed in previous researches. Moreover, the employed risk management method has been described. Data collection and analyses are presented. Then, according to the analyses, the high risks are identified and separated and for each of them, responding methods have been proposed and discussed thoroughly. Finally, concluded points from this study will be presented, together with some recommendations for future works. These steps are divided into six separate chapters as follows:

Chapter 2, the literature review, consists the previous research works on risk management and their brief results.

Chapter 3, the methodology, describes the selected methods of performing this research study. For the data collection section, moreover, the most proper method of analysis is chosen. The method of performing further analysis is also completely described.

In chapter 4, the obtained results from the checklists and the outcomes of risk identification from various viewpoints of each respondent are provided in forms of tables and figures.

In chapter 5, the analyzed data and their results are discussed thoroughly. The main reasons of high risks are specified and for each of them, recommended responses are provided and explained.

Finally in chapter 6, conclusions and recommendations, the main conclusions are briefly explained and some recommendation for future studies are provided.

The schematic representation of thesis outlines is provided in Figure 1.1.

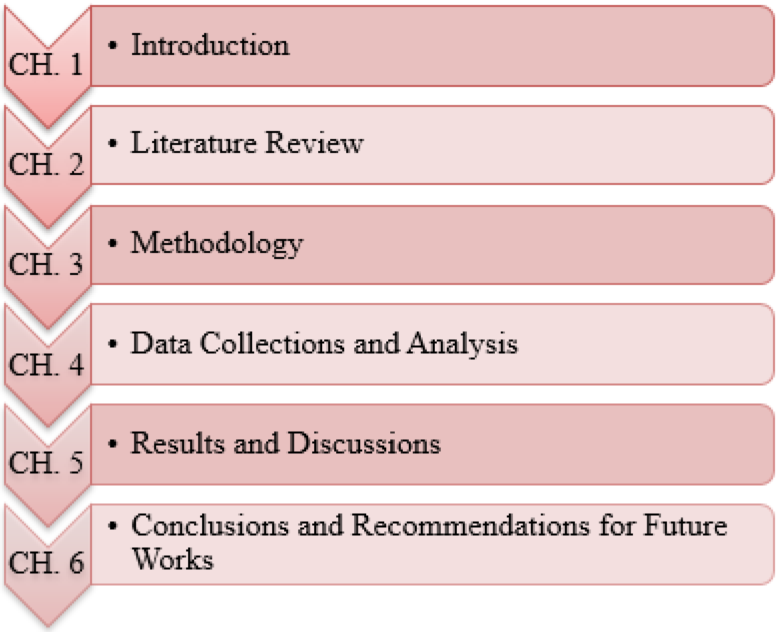

Figure 1.1: Thesis framework

Chapter 2

LITERATURE REVIEW

2.1 Introduction

Construction industry is a huge sector in many countries. In most of the developing countries, this sector has a main share in the Gross Domestic Product (GDP) rate. Moreover, its influence on growth of the employment ratio has also made it one of the most important industries (Rezaie, 2011).

Construction industry is usually divided into three main categories as follows:

- Building construction industry
- Heavy construction industry
- Special trade construction industry

On the other hand, since there is a high-risk exposure mostly associated with the construction projects, employing risk management analyses seems to be vital.

Massive researches and advances have been done recently about risk management in construction projects and it is already recognized as one of the most critical procedures of project management (Klemetti, 2006).

According to one of the latest Project Management Body of Knowledge editions, risk management is now known to be one of the ten knowledge areas, which its knowledge and employment is very crucial in every project (PMI, 2013).

Project Risk Management (PRM) is meant to reduce the probability of failure of projects and let the projects result at an acceptable level. It is expected that by employing this method, the beneficial and desirable consequences of projects become maximized, besides minimization of adverse outcomes.

In this chapter, it is aimed to explain the backgrounds of this research field from various viewpoints as well as discussing the related problems. In the following sections, the key concepts of risk and risk management will be explained and different stages of the analysis process as well as the available tools and techniques will be discussed.

2.2 Definition of Project Risk

Although there are different viewpoints about the concept of risk and actually this word has different meanings to diverse groups of people (Baloi & Price, 2003), most of the times negative attitudes are being associated with the concept of risk. In other words, in most cases, shortcomings such as loses or damages are being counted as the outcomes of risking and positive advances of it, such as gains and benefits are nearly neglected (Al-Bahar & Crandall, 1990).

There are undoubtedly various definitions given for the word "risk", from the projects' risk management viewpoint (Baloi & Price, 2003). In spite of their differences, a common feature is noticeable between them, which is the point that risk is usually defined as an uncertain and unexpected event, which may also change the project's objectives widely or narrowly.

According to an international standard for project risk management, risk is defined in terms of probability of an event, and its effectiveness. Using these terms, risk is defined as a consideration of both probability of occurrence of an event and also how its occurrence influences the objectives and outcomes of the project (British Standards , 2001).

According to PMBOK (2013), risk is defined as “an uncertain event or condition that if occurs, has a positive or negative effect on one of project objectives” (PMI, 2013).

Ward and Chapman (2003) viewed risk as a more general idea of uncertainty and discussed more about the fact that usually negative sides and threats of this concept is considered, without viewing the opportunities that may also be its consequences. Table 2.1 shows two categories of risk definitions in literature.

Table 2.1: Two different definitions of “Risk” in literature (Breysse, 2009)

Risk : the measure of consequences	**Risk: the source event**
ISO guide draft 73 (2009) Effect of uncertainty on project objectives. An effect is a deviation from the expected positive and/or negative objectives.	Chapman (2001) an event, which should it occur, would have a positive or negative effect on the achievement of a project's objectives
WSDOT (2010) The combination of the probability of an uncertain event and its consequences. A positive consequence presents an opportunity; a negative consequence poses a threat.	PMI (2008) (PMBOK) project risk is an uncertain event or condition that, if it occurs, has a positive or negative effect on a project’s objectives.
ITIG (2006) Risk is a function of the consequence/severity of a hazard and the likelihood of occurrence of the hazard.	Del Cano and Cruz (2002) an uncertain event that, if it occurs, has a positive (opportunities) or negative (threats) on a project objective.
Bourdeau et al. (2003) Expectancy of undesirable results (but the occurrence of positive results can be integrated).	Baloi and Price (2003) The likelihood of a detrimental event occurring to the project.
Raftery (1999) Exposure to the possibility of economic and financial loss or gain, physical damage or injury, or delay as a consequence of the uncertainty associated with pursuing a particular course of action.	Al-bahar and Crandall (1990) The exposure to the chance of occurrences of events adversely or favorably affecting project objectives as a consequence of uncertainty.

A research instance to certify this claim has been conducted by Akintoye and MacLeod (1997) in the form of a questionnaire. The results showed that the majority of participants had negative opinions about the concept of risk and did not consider the possible opportunities associated with them. It means having more concern about the threats of risks instead of being motivated to grab their opportunities.

2.2.1 Risk versus Opportunity

As aforementioned, consideration of risks threats is the predominant opinion; however, recent standards and guidelines are also incorporating the probability of positive results and opportunities, which are in fact the uncertain, favorable impacts of risks on the objectives of project (Hillson, 2002).

In fact, risk as a general term is classified into threats and opportunities and in a project risk management process, it is vital to state both of them (threats and opportunities) accompanied.

In the following sections, risk concept will be explained more with an inclination towards the threats accompanied by it, than on opportunities.

2.3 A Concept of Risk Management

In terms of threats and opportunities, risk management is aimed to maximize the positive events (opportunities) and minimize the adverse events (threats). It is a regulation and guideline of living with the awareness of possible undesirable effects of future events (Flanagan & Norman, 1993).

Consideration of risk management in projects will lead to have a better understanding of possible results of probable risks, and will guide us in avoiding them. (Perry, 1986).

The following sections are mainly dealing with project management process in construction sector.

2.4 Risks in Construction Projects

In construction projects, due to having the high potential of threats, because of their characteristics, risk management is considered as a crucial process and the method is widely employed. Regardless of the aim, scope and the size of project, various forms of threats can be identified in every single project.

In every construction project, a key point is to keep an optimized balance between cost of the project, construction time, its quality, and the safety level.

Management of risks in the projects is in fact an orderly method of identifying the threats, assessing their impacts and responding to them, to reach the objective of project (PMI, 2008).

Benefits of risk management are well known and many researchers have highlighted its benefits in construction industry. It is claimed that risk management gives a better understanding of possible unmanaged threats and their effects and has more operative solution procedures (Smith et al., 2006).

Construction projects risk management is known to be very fundamental in order to fulfill the main objectives of a usual project, regardless of its size. The objectives obviously are not limited to the performance of the project, but there are actually various targets that must be satisfied such as construction time, quality, cost, and health and safety during the performance (Zou et al., 2007).

Following heading will be mainly about different risk management processes based on various definitions and viewpoints proposed by different researchers. In each method, steps are explained together with some examples and finally one method is chosen for further risk analysis.

2.5 Project Risk Management Process

As mentioned previously, risk management is a process of identifying, evaluating and responding to the risks during the project in order to maximize the opportunities and minimize the threats.

The concept of risk management is a durable process, done all the way through the project's life. A typical process of risk management initiates with risk identification. It is strictly kept in mind during the project planning as well as project execution, monitoring and controlling, when issues are exposed and decisions are made accordingly (Mulcahy, 2010). Having all these steps, more or less, in common, there are diverse management models having different number of stages.

In one method, the stages are classification of risks, identification of them, analyzing risks and risk response. In this method, risk response is itself separated into four stages of avoidance, transferring, risk reduction, and retention (Flanagan & Norman, 1993).

Another model has been proposed by the international standard of project risk management, incorporating the four steps of identification, assessment, treatment, and reviewing and monitoring of risks during the project (British Standards , 2001).

Risk management planning, risk identification, its qualitative and quantitative analysis, response planning, and monitoring and controlling are the steps of another model of risk management, which is also shown in Figure 2.1 and has been proposed by Project Management Institute (2009).

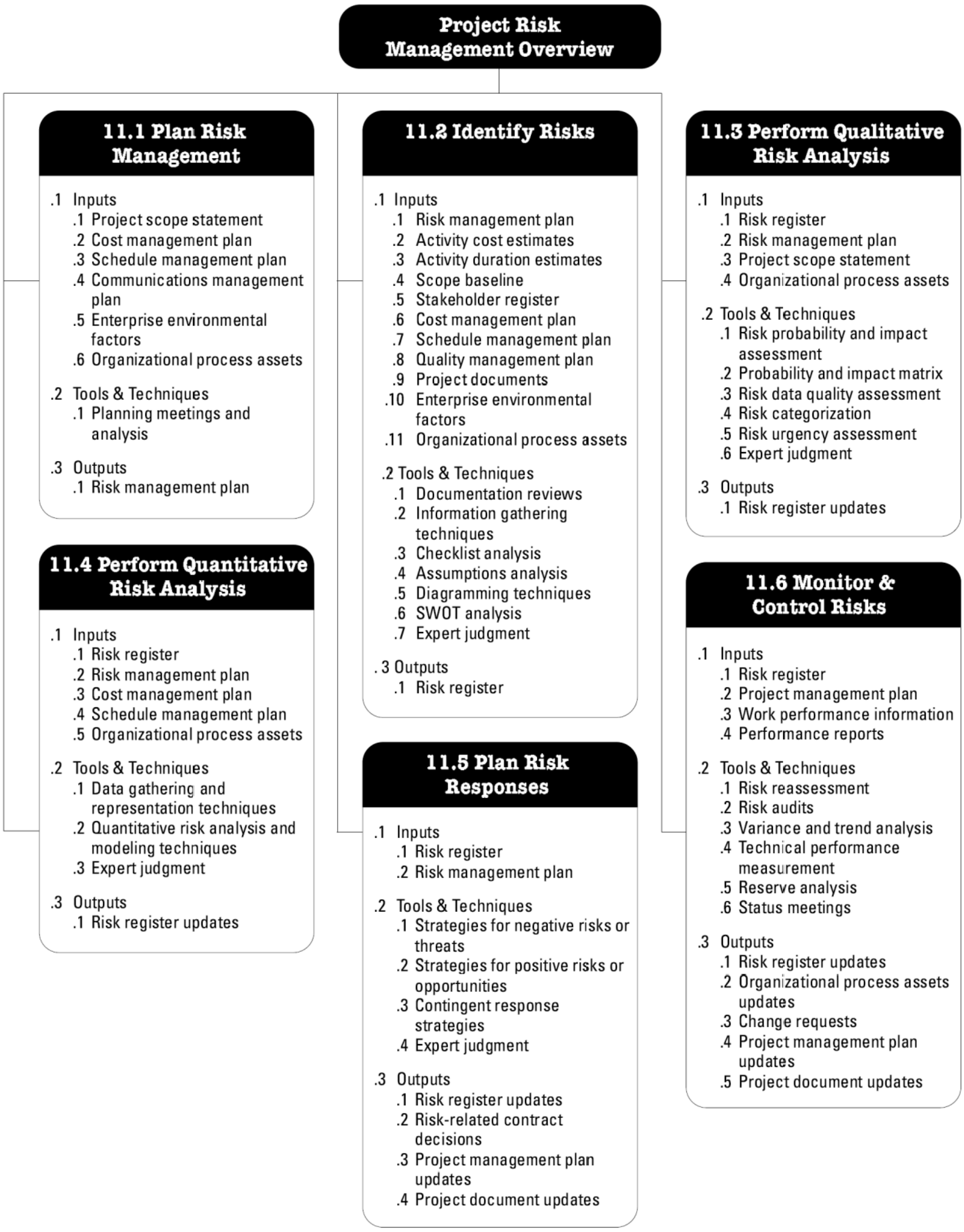

Figure 2.1: Project Risk Management overview (PMI, 2009)

The process of risk management, as being crucial to have a better understanding and monitoring of project risks, has led to another model suggested by Smith et al. (2006) and it is shown in Figure 2.2. Moreover, in Figure 2.3, a schematic representation of Risk Management Process (RMP) recommended by Tah and Carr

(2001) has been shown. The steps are shown and in each step, the input data, necessary tools and methods, as well as expected outputs are provided.

Figure 2.2: Schematic representation of risk management procedure (Smith et al. (2006))

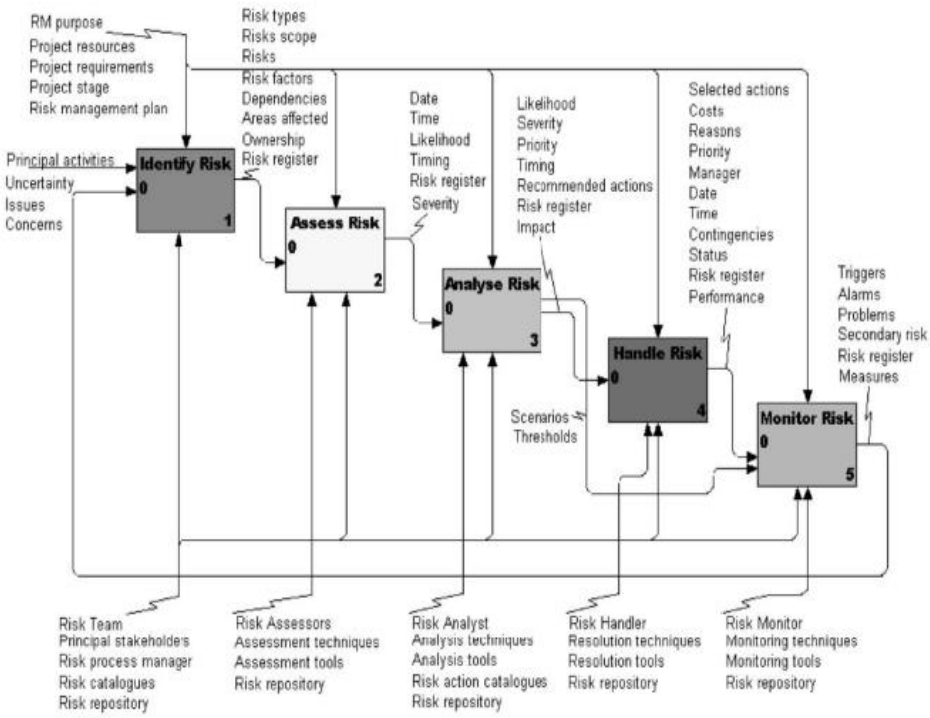

Figure 2.3: The Risk Management Process (RMP) (Tah and Carr, 2001)

It worth mentioning that although the methods are different, they have identical features and their goals are the same, which is to identify the risk sources, qualify and quantify their effects, determine the risk responses and finally controlling and monitoring them.

In this research, the risk management model of Smith et al. (2006) (Figure 2.2) is employed in the analysis, because it is included all the important phases of risk management. Having described risk identification, assessment and response, complete information about the process of risk management will be presented.

2.5.1 Risk Identification

Identification of risks is the very first stage of risk management process since, as the risks are not identified, they obviously cannot be managed. Thus, after the initial step of planning the risk management, all recognizable risks to the project's objectives should be identified (PMI, 2009).

The desirable objective of this stage is to have the longest list of possible risks (Mulcahy, 2010).

In the risk identification stage, the related risks of construction project are identified, classified and their consequences are evaluated continuously and steadily (Al-Bahar & Crandall, 1990). According to Practice Standard, for Project Risk Management (2009), the main aim of risk identification is finding the possible risks, and put them in a list, which is known as risk register, associated with the project and their consequences (both negative and positive) on the outcomes of project.

Identification is also not an all at once stage, but it should be performed regularly throughout the project with the purpose of recognizing risks as much as possible. The fact is that risk identification must be an iterative repeating process to get a better estimation of which risks are probable, due to unknown or emergent risks that may occur during the project (PMI, 2009).

The whole project team must be involved in the process of risk identification to grow a sense of responsibility about the project, risk identification and supplementary risk response actions.

A wide range of experts including project manager, team members, the risk management team of the project (if assigned), and other stakeholders are contributors to the risk identification stage (Mojtahedi et al., 2010). Risk identification is the very first practical stage of risk management; therefore, it can be said that the success or failure of the consecutive stages (of risk management) is strongly dependent on this stage (Chapman, 2011).

The importance of risk identification stage is intensively crucial that it has been claimed to be the most beneficial stage of risk management, instead of risk analysis (Winch, 2010).

Risk identification stage must be employed in an equal manner to determine both threats and opportunities of all the identified risks. However, according to the experiences, it is suggested that the identification of risks should be more focused on the threats and negative issues of risks. Input data of this stage are the objectives of projects, the scope, plan and the relevant historical data (Hillson, 2002).

Extensive range of tools and techniques are available to perform risk identification, including brainstorming and workshops, checklists and prompt lists and etc. Moreover, there are also diagramming methodologies such as cause-effect diagrams, systems dynamics and influence diagrams (Chapman, 2011). These methods will be explained briefly in the following sections.

2.5.1.1 Brainstorming

This method is one of the methods, which are being employed to create a broad range of risks and threats, resulting in raising ideas and solving problems. Therefore, it is very popular in risks and project management issues identification (Mulcahy, 2010). The method is in the form of an open debate, with all the participants discussing their ideas on various risks to find out how uncertainties may change into risks (Smith et al., 2006).

2.5.1.2 Checklist analysis

This method is fundamentally based on the previous data collections and historical information, collected from various sources of information, including similar projects. The checklist can also be arranged about the risk breakdown structure, whose lowest level can form the risks checklist (PMI, 2013).

2.5.1.3 Expert interviews

Interviews that are meant to be performed in the stage of risk identification must be done with all the chief stakeholders and should be conducted by a trained interviewer, in an honesty and mutual trust atmosphere following a structured schedule. To have a more structured interview, a prompt list, a risk breakdown structure or a checklist can be employed (PMI, 2009).

2.5.1.4 Nominal group technique

This technique is a useful method when groups of people's attitudes are meant to be found out instead of single individual ones. In this field, the group may be a department, minor stakeholders or the people who want to be stakeholders. The result of nominal group technique is to know how much the focused group's general opinion about the risks of a project is agreed and supported (Mulcahy, 2010).

2.5.1.5 Delphi technique

Another useful technique is called the Delphi technique, which is again a method to identify the probable risks of a project by means of gathering anonymous polls of the specific issue's experts. The expert's initial responses are gathered and then are announced, without being attributed to those groups who may re-think about their contribution, due to others' contributions or comments (PMI, 2013).

In the Delphi technique, a set of serial questionnaires are designated based on previous responses and surveys, in order to collect and organize decisions and opinions of unidentified participants about a specific topic (Chapman, 2011).

2.5.1.6 Questionnaire

A checklist of possible and likely risks can be provided as a risk identification questionnaire to simplify the identification of the possible risks (PMI, 2013).

2.5.1.7 Work Breakdown Structure (WBS)

Work Breakdown Structure (WBS) is a crucial idea to identify and diagnose possible major or minor risks. From its title, it is easy to have the general idea about this method, in which the major steps and activities are firstly broken down into small, controllable and linked steps (Maylor et al., 2005). After identifying the potential risks, they can be tracked at summary, work packaged levels and control accounts (PMI, 2013)

2.5.1.8 Risk Breakdown Structure (RBS)

This method is another handy method which gives out an outline about the risks that may happen during the project. It is a widely used method during various stages of project's risk management, including risk identification, and delivers further supports in far ahead stages (risk assessment, response and monitoring). A schematic illustration of this method is shown in Figure 2.4.

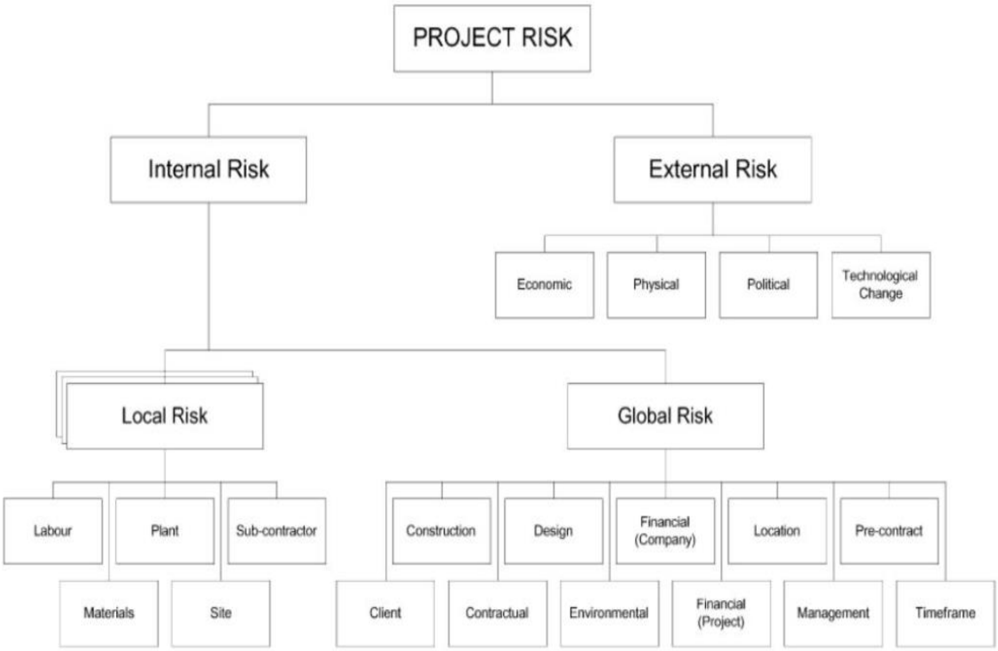

Figure 2.4: Example of a Risk Breakdown Structure (Carr & Tah, 2001)

The subsequent paragraphs are mainly including short definitions and explanations about different risk management concepts. Actually they have been provided to avoid confusions in this research, since in different sources and standards, there are sometimes altered definitions given for the concepts.

- **Risk factor:** Risk factors are those, which their combination may result in a potential loss, harm or injury. Risk factors do not affect projects or activities directly, their effect is mainly received through the risks events (Carr & Tah, 2001; Jeynes, 2012).

- **Risk event (RE)**: These are any of the facts or events, which are influenced by risk factors, and are influential on all or at least one of the objectives of the project (Carr & Tah, 2001).

- Risk category (RC): Risk category is a method to classify several risk events. Any category can also have further subcategories, to give out a more detailed view. On the other hand, to give a more general view, categories can also be merged together.

Risk register: Identification process of a risk management does not only deal with identifying the potential risks, but also includes their classification, understanding their causes, their properties, their signs, how they are distributed, what might be their consequences, and which primary responses are required to challenge with them. Employing all these precious data, a document of risks can be provided which can be helpful to the project team throughout the project to review the risks and take the necessary actions. Such a document is called the risk register. Not surprisingly, there have also been efforts to establish a list of necessary items to be recorded in a risk register. One of them has been created by Patterson and Neailey (2002) in which for every single potential risk, the following information must be provided. The type of risk, what causes it and its descriptions must be explained. In which stage or phase, and state (apparent or latent) it happens, and which impacts it has, should be provided. The probability (both qualitative and quantitative) and distribution of its occurrence, the methods of responding to it (avoiding, transferring or mitigating) and their required resources must be revealed and finally, it should be provided that which types of connections might occur between this risk and other risks and responses (Patterson & Neailey, 2002).

Table 2.2 provides a list of available tools of risk identification, listing each ones' positive and negative points.

Table 2.2: Risk identification tools and techniques (PMI, 2009)

Technique	Strengths	Weaknesses
Assumptions & Constraints Analysis	–Simple structured approach –Can be based on assumptions & constraints already listed in project charter –Generates project-specific risks	–Implicit/hidden assumptions or constraints are often missed
Brainstorming	–Allows all participants to speak their mind and contribute to the discussion –Can involve all key stakeholders –Creative generation of ideas	–Requires attendance of key stakeholders at a workshop, therefore can be difficult to arrange and expensive –Prone to Groupthink and other group dynamics –May produce biased results if dominated by a strong person (often management) –Often not well facilitated –Generates non-risks and duplicates, requires filtering
Cause and Effect Diagrams (Ishikawa, 1990)	–Visual representation of project promotes structured thinking	–Diagram can quickly become over-complex
Check List	–Captures previous experience –Presents detailed list of risks	–Check list can grow to become unwieldy –Risks not on the list will be missed –Often only includes threats, misses opportunities
Delphi Technique	–Captures input from technical experts –Removes sources of bias	–Limited to technical risks –Dependent on actual expertise of experts –May take longer time than available due to iterations of the experts' inputs
Document review	–Exposes detailed project-specific risks –Requires no specialist tools	–Limited to risks contained in project documentation
FMEA/Fault Tree Analysis	–Structured approach, well understood by engineers –Produces an estimate of overall reliability using quantitative tools –Good tool support	–Focuses on threats, not so useful for opportunities –Requires expert tools not generally available to those except experts
Force Field Analysis	–Creates deep understanding of factors that affect project objectives	–Time-consuming and complex technique –Usually only applied to a single objective, so does not provide whole-project view
Industry knowledge base	–Captures previous experience –Allows benchmarking against external organizations	–Limited to what has previously happened –Excludes project-specific risk
Influence diagrams	–Exposes key risk drivers –Can generate counterintuitive insights not available through other techniques	–Requires disciplined thinking –Not always easy to determine appropriate structure

Interviews	–Addresses risks in detail –Generate engagement of stakeholders	–Time consuming –Raises non-risks, concerns, issues, worries etc, so requires filtering
Nominal Group Technique	–Encourages and allows all participants to contribute –Allows for different levels of competence in common language –To a large extent, auto-documenting –Provides ideal base for affinity diagramming (grouping by risk categories for use in the Risk Breakdown Structure and Root Cause Analysis)	–Can lead to frustration in dominant members who feel it is moving slowly
Post-project reviews/ Lessons Learned/ Historical Information	–Leverages previous experience –Prevents making the same mistakes or missing the same opportunities twice –Enhances the Organizational Process Assets	–Limited to those risks that have occurred previously –Information is frequently incomplete: details of past risks may not include details of successful resolution; ineffective strategies are rarely documented.
Prompt Lists	–Ensures coverage of all types of risk –Stimulates creativity	–Topics can be too high level
Questionnaire	–Encourages broad thinking to identify risks	–Success depends on the quality of the questions –Limited to the topics covered by the questions –Can be a simple reformatting of a checklist
Risk Breakdown Structure (RBS)	–Offers a framework for other risk identification techniques such as brainstorming –Ensures coverage of all types of risk –Tests for blind spots or omissions	–None
Root-Cause Analysis	–Allows identification of additional, dependent risks –Allows the organization to identify risks that may be related because of their common root causes. –Basis for development of pre-emptive and comprehensive responses –Can serve to reduce apparent complexity	–Most risk management techniques are organized by individual risk. This organization is not conducive to identifying the root causes –Can oversimplify and hide existence of other potential causes –There may be no valid strategy available for addressing the root cause once it has been identified.
SWOT Analysis	–Ensures equal focus on both threats and opportunities –Offers a structured approach to identify threats and opportunities –Focus on internal (organizational strengths and weaknesses) and external (opportunities and threats)	–Focuses on internally generated risks arising from organizational strengths and weaknesses, excludes external risks –Tends to produce high-level generic risks, not project-specific
System Dynamics	–Exposes unexpected inter-relations between project elements (feedback and feed-forward loops) –Can generate counter-intuitive insights not available through other techniques –Produces overall impacts of all included events and risks	–Requires specialized software and expertise to build models –Focuses on impacts but difficult to include the concept of probability
WBS Review	–Ensures all elements of the project scope are considered –Provides for risks related to different levels of detail (from high-level to those related to individual work packages)	–Excludes external risks or those not specifically related to WBS elements

2.5.2 Risk Analysis

This stage is the key connection between the identification of potential risks of a project and the management of them, especially the substantial ones. This stage is mainly dealing with the evaluation of risks, their possible impacts on the objectives and how they can be effective by means of risk analysis and measurement methods (Flanagan & Norman, 1993). An important result of performing this stage is ordering and giving priority to the identified risks for the necessary supplementary actions.

The necessary required data to perform this stage are those collected in the first stage, risk identification. Among them, the identified risks, their occurrence probability and their impacts are the crucial data for evaluation and analysis of the risks. Both qualitative and quantitative risk analyses must be performed in order to specify the risks, which deserve a response (Mulcahy, 2010).

2.5.2.1 Qualitative analysis

Qualitative analyses are clearly based on nominal scale and the descriptions that are given about the risky events and their consequences. Most of the times, this method of assessment is used, when a rapid, initial evaluation is needed, especially in the case of not having enough knowledge about the probabilities or impacts of the risks. It is known as a process without any numbers or measurements. This process is desired to be performed since it gives priority to the identified risks. The prioritized and ordered risks will then be employed as the input data in quantitative analysis, involving probability of occurrence, measurements and impacts. Judgments, comparisons, rankings and descriptions are all considered as qualitative analyses (Flanagan & Norman, 1993).

One of the outcomes of this evaluation is identifying the risks that have the most significant influence on the objectives of the project (PMI, 2013).

Particular aims of performing qualitative risk analysis are evaluating the probability and the impacts of the risks (qualitatively), separately. By means of this evaluation, a rapid shortlist of risks will be created, showing the most critical risks to be quantified by using numbers and measurements. Having these analyses and results, another crucial decision can also be made easier, which is whether it is worth performing this project, or not (Mulcahy, 2010).

Although this analysis is very handy and beneficial, it is usually being employed in the small or at most medium-sized projects, with comparatively lower complications (Smith et al., 2006). As aforementioned, qualitative analysis should be performed when there is a lack of numerical risk data.

Risk Probability and Impact: In each project, besides identifying the potential risks, it is deeply important to investigate the probability or likelihood of occurrence of each of them, in addition to the evaluation of their impact on the project's objectives, i.e. cost, time, etc. These aims are fulfilled through questionnaires, interviews and checklists (PMI, 2013).

In this method, risks occurrence probabilities and their impacts are evaluated and described, using the terms of very high, high, moderate, low and very low. A numerical scale has also been allocated to these probability levels (from 1 to 5). Two main definitions are involved in the analyses, which are the risk probability and risk impact. The first one is obviously showing the possibility of risk occurrence, and the second one is the impact of the risk on the objective, if it occurs (Mulcahy, 2010).

Tables 2.3 and 2.4 show a sample of scale condition for both probability and impact of risks (HSE, 2009; NPSA , 2008; PMI, 2013).

Table 2.3: Scoring scale of risk probability (HSE, 2009; NPSA, 2008)

Probability Category	Probability	Description
Very High	5	Risk event expected to occur
High	4	Risk event more likely than not to occur
Moderate	3	Risk event may or may not occur
Low	2	Risk event less likely than not to occur
Very Low	1	Risk event not expected to occur

Table 2.4: Scale of influential impacts on different objectives (PMI, 2013)

Defined Conditions for Impact Scales of a Risk on Major Project Objectives (Examples are shown for negative impacts only)					
Project Objective	Relative or numerical scales are shown				
	Very low /1	Low /2	Moderate /3	High /4	Very high /5
Cost	Insignificant cost increase	< 10% cost increase	10 – 20% cost increase	20 – 40% cost increase	> 40% cost increase
Time	Insignificant time increase	< 5% time increase	5 – 10% time increase	10 – 20% time increase	> 20% time increase
Scope	Scope decrease barely noticeable	Minor areas of scope affected	Major areas of scope affected	Scope reduction unacceptable to sponsor	Project end item is effectively useless
Quality	Quality degradation barely noticeable	Only very demanding applications are affected	Quality reduction requires sponsor approval	Quality reduction unacceptable to sponsor	Project end item is effectively useless
This table presents examples of risk impact definitions for four different project objectives. They should be tailored in the Risk Management Planning process to the individual project and to the organization's risk thresholds. Impact definitions can be developed for opportunities in a similar way.					

Probability and Impact Matrix: Having done the probability evaluation of risks and investigating their impacts, they should be arranged in order to meet the project's purposes. A very handy tool that is mostly employed to prioritize the risks in qualitative analysis, is called probability and impact matrix. Determination of each risk's priority is done by multiplication of the risk's impact, by the risk's probability. In the matrix, priorities are shown by different colors, so one can easily understand how the risks are actually ordered (Westland, 2007).

Risk rating: Risk rating is a number that is allocated to the probability of the risk occurrence or its impact and is varying from 1 to 5.

Risk score for each risk: Risk score is in fact a numerical value defined for each risk and is equal to the multiplying impact of risk by its probability.

Risk ranking within the project: Within a single project, risk rankings are done through comparing the risk scores. The risk with the highest score becomes the first top-ranked, the second score becomes the second top-ranked, etc. (Mulcahy, 2010).

Table 2.5 show the probability and impact matrix on project objectives (PMBOK, 2013).

Table 2.5: Matrix of probability and impact, affecting the objectives (PMBOK, 2013)

Probability and Impact Matrix

Probability	Threats					Opportunities				
5	5	10	15	20	25	25	20	15	10	5
4	4	8	12	16	20	20	16	12	8	4
3	3	6	9	12	15	15	12	9	6	3
2	2	4	6	8	10	10	8	6	4	2
1	1	2	3	4	5	5	4	3	2	1
	1/ Very Low	2/ Low	3/ Moderate	4/ High	5/ Very High	5/ Very High	4/ High	3/ Moderate	2/ Low	1/ Very Low

Impact (numerical scale) on an objective (e.g., cost, time, quality, health and safety)

Each risk is rated on its probability of occurring and impact on an objective if it does occur. The organization's thresholds for low, moderate or high risks are shown in the matrix and determine whether the risk is scored as high, moderate or low for that objective.

After this stage, the risk matrix tool will be employed to show visually the level of risks by assigning different colors. The high risks (the most critical) in the matrix will be colored dark gray that must be definitely considered for the future qualitative risk analysis or plan risk responses process.

The middle ranges of matrix colors are assigned to moderate risks with light gray. These risks should also be concerned, and considered in the plan risk responses process, but the sensitivity about them is not at the same level of the top-ranked ones.

Finally, the risks having the lowest scores will also be indicated in the matrix, but in a different color, which is medium gray. These risks can be accepted without any necessary investigations or responses since they have minor impacts and low occurrence probability (PMI, 2013; Mulcahy, 2010).

It is suggested that each organization should have an agreement on the interpretation of the risk matrices colors, and must have an established criteria to decide which risks are accepted, which ones are not and why (Flanagan & Norman, 1993).

2.5.2.2 Quantitative analysis

As aforementioned in qualitative analysis, risks and the ranking of them are done without employing any actual numerical data. From this viewpoint, opposed to qualitative analysis, quantitative analysis is performed to provide actual numerical information about the project's risk features and impacts by means of real numerical value of risks' probabilities and impacts. The essential numerical data of quantitative analysis are achievable from expert's estimated or historical databases. Results of this analysis should be compared to the principles, utilized by managers and decision makers, to accept or reject a potential risk (Baker et al., 1998).

Some of the practical aims of performing quantitative analysis are to know which potential risks should be responded. To evaluate the current risk of the project, and decide about if this level of risk is acceptable for the anticipated outcome of the project, estimate the projects future costs, and performance time, if no more risk management actions are considered to decrease the risks (Mulcahy, 2010).

Figure 2.5 indicates a comparison between the qualitative and quantitative risk analyses of projects.

Figure 2.5: Comparison of the outputs of qualitative and quantitative approaches (PMI, 2009)

It should be implied that the mentioned stages (risk identification, scoring, etc.) are inter-related and indeed, there is a vital connection between them and the other stages of risk management. In other words, to have a successful and effective quantitative risk analysis, a proper model for project must be employed, risk interactions must be considered, risk data collections must be done unbiasedly and sensibly, and an operative risk identification and qualitative analysis must be performed (PMI, 2009).

In the stage of quantitative analysis, it is aimed to measure the risks and their combinations effects on the project's objectives, by means of some techniques such as Monte Carlo analysis, decision trees, and sensitivity analysis. These techniques deal with creating a model for the whole project or its key elements, introducing the identified risks or uncertainties into the model, and analyzing their effects and their combinations effects on the project's consequences (Hillson, 2002).

These techniques are listed as follows and will be explained more, in the subsequent paragraphs.

- Monte Carlo Simulation: Scenario technique
- Decision trees: Diagraming technique
- Sensitivity analysis: Modeling technique

Scenario technique - Monte Carlo Simulation: this simulation technique is used in predicting, assessing and risk analysis of a project, by considering different states and generating various scenarios. It can be employed to determine the project's costs and how long it will take to be performed. It is obvious that to create an exact and trustable Monte Carlo analysis, the model must be provided by accurate data. So, this method is actually based on the statistics, which are necessary to simulate and assess the risks of a project. In most cases, the data that are being employed in this technique are the previously obtained data, from earlier similar projects. Admittedly, it is crucial for a company to develop a database of its projects, including the time schedule and costs of each single performed step, over the time, in order to use them to set up a more accurate and trustable risk analysis. Obviously those employed data are also different and contain different states, i.e. pessimistic, the most probable and optimistic (Heldman, 2005) .

The most common method of performing this analysis is employing one of the various known risk simulator software programs, such as Pertmaster and Risk+ or simply using the popular Microsoft Excel, in which a special function is defined to choose data randomly. However, despite being simple and user-friendly, the results can also be very limited and not adequately general (Mun, 2006).

Diagraming technique - Decision trees: Decision tree is known to be another method of performing the risk analysis of projects. Based on a graphical model, having a decision node and a chance node, this technique is mostly utilized in conditions in which the occurrence possibility of an event is affected, during decision-making (Flanagan & Norman, 1993; Smith et al., 2006).

The chance and decision nodes in this method represent potential risks and necessary decisions, respectively. The risky events are connected to each other by arrows and they can well-illustrate how different events are correlated to each other. This method is a very popular method, especially when the project has complicated scenarios.

In this technique, future states and scenarios are considered to make better decisions and the expected monetary value (probability multiplied by impact) is calculated for more complicated situations (Mulcahy, 2010).

It should be explained that the expected monetary value is a method of predicating the cost of project or its performance duration (Mulcahy, 2010).

Modeling technique - Sensitivity analysis: Sensitivity analysis is done to find which risky events have the maximum impacts on the objectives of project. In a specific risk event, the greater level of uncertainty means that this risk is more likely to affect the objectives and is more critical, so stronger actions should be considered for it (Heldman, 2005).

It is suggested that this analysis be performed in the initial stages of a project, in order to have a better and more accurate monitoring and concentrating on the serious issues throughout the project. To perform it by computer software, a model of project is needed and its results can be presented in the form of a spider diagram (Smith et al., 2006).

2.5.3 Risk Response Planning

During this stage, having done the necessary analyses in previous stages, the major risks are focused and it is tried to find options and effective, suitable actions to confront with their threats with minimizing them and benefit from their opportunities. It mainly deals with defining the suitable response actions to the general project's risks and the individual potential known risks considering their priorities. This step is mainly performed by considering the stakeholders' risk opinions, risk management plan, and the restrictions and assumptions determined in the previous stages of risk identifications and analyses. As the responses are decided and applied, due to new actions, it is more likely to have new risks possibilities, which are known as secondary risks, and the same stages of analyzing and planning must be done for them as well (PMI, 2009).

The known response approaches for possible threats are listed as follows. It is also possible to use a combination of them as well.

Mitigation: This method is known to be the most applicable method and consists of actions, which lead to reduction of the threats probabilities or the impacts of risks to an acceptable level. Necessary mitigation actions are likely to consume time and resources as well. Some of the real mitigation strategies are known as changing the approach of completing an activity, using more simple processes, increasing time, changing or adding resources, benefitting from more sophisticated experts, postponing the activities or reschedule them to be done earlier, or to reduce the probability (Mulcahy, 2010).

Avoid: Avoiding a risk means that any exposure to the potential risk is not allowed anymore. Risk avoidance is implemented when there is no chance for the risk to be accepted by the organizations or the individuals dealing with it.

To avoid a potential risk, the project plan is changed so that the projects objectives (cost, time, etc.) are protected from its threats. There are several methods to avoid a potential risk such as assigning conditions on the bids, not bidding on the high risk section of project, pre-condition negotiations to assign which party takes certain risks (Baker et al., 1998).

Transfer: This strategy is not necessarily eliminating the threats of a risk. Instead of eliminating, transferring a risk passes the threats and concerns of a risk to a third party or another partner involved in the project. Logically it is suggested that the risk should be transferred to a portion, which is better and more expert. Numerous methods of transferring risks are being employed these days, such as using warranties, insurances, guarantees and etc. A commonly used transferring strategy is done when the financial impacts of risks are transferred to an insurance company.

Accepting: acceptance of a risk is employed when no other strategy is found to be feasible and reasonable. It actually means not become involved in the risk, unless it is occurred. In this case, there must be a balance between the threats and opportunities of the risk. Acceptance can be either active or passive. In active acceptance, some contingency or fallback plans are developed and set to be done when the risk happens, opposite to the passive acceptance in which, no initial plans are made.

Although the threatening potential risks are usually explained more and are believed to be more crucial, an appropriate risk response is the one addressing the opportunities of risks as well. Possible responses to opportunities are known to be exploiting, enhancement, sharing and acceptance. Likewise threats responses, a combination of these are also possible. Figure 2.6 is schematically showing the possible responses to threats and opportunities in a matrix form as a function of risk probability.

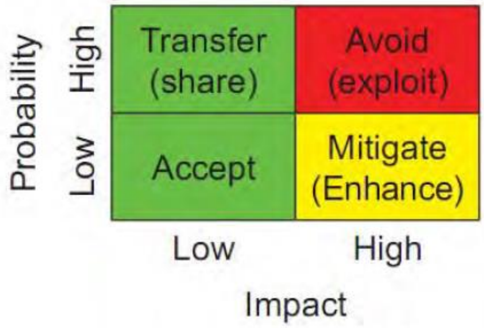

Figure 2.6: Simple response matrix proposed by WSDOT (2010)

In the matrix (Figure 2.6), high impact and high probability zone means that immediate suitable action should be taken, i.e. in the case of threats or opportunities, they should be avoided or exploited. While green zones (low impact risks), do not require immediate responses.

Outputs of the risk response process plan are as follows:

- Residual risks: Which are those remained after the responses, such as accepted risks, for which their relevant contingency and fallback plans can be made. Documentation, revision and monitoring these risks must be done throughout the project.
- Changes in the project plan.
- Secondary risks: Are the risks, which are actually produced by risk responses. In other words, when a risk response action is decided and taken, it may cause secondary risks. These risks must also be included in the risk response plans, evaluated and analyzed and necessary actions should also be taken for them. Definitely, it is not

accepted that a secondary risk be stronger and more crucial than the initial risk (Mulcahy, 2010).

- Triggers: Triggers are the initial signals that announce the occurrence of an accepted risk, so that the project executors or risk owners should become prepared to handle it by a contingency strategy or in the case of its failure, by a fallback one.

- Contingency plan: Contingency plans include necessary reactions or tactics that are set to be performed at the occurrence of a risk (Mulcahy, 2010).

- Fallback plans: These plans or strategies are in some ways the next step after the failure of contingency plans (Mulcahy, 2010).

- Reserves: Reserves are the additional time or cost that are added to the project, to comprise with the potential risks. Two categories of reserves are called as contingency reserves and management reserves. Contingency reserves are set to be dealing with the known unknowns, i.e., the identified residual risks that remain after risk response planning. Management reserves are applicable to the unknown unknowns' risks that have not been identified (Mulcahy, 2010).

- Risk response plan.

2.5.4 Controlling and Monitoring the Risks

As the project is being performed, new facts about it will be revealed so the project's risk list changes. New risks might be added and some anticipated risks may also be deleted. Therefore, it is vital that the risk management plan is kept updated constantly. In other words, the project manager should guarantee that risk identification, evaluations and analysis, and the risk responding lists are renewed at realistic and practical time intervals, or in responding, the new events occurred in the project.

Risk monitoring is the group of actions that follows the identified, residual, secondary and the newly identified risks during the progress of project, besides controlling the implementation of the decided strategies and assessing their efficiency. This stage has to be continued in the whole lifetime of the project (Office of Statewide Project Management Improvement , 2007).

By monitoring and controlling the risks, it is aimed to keep track on the projects' decided strategies, management and response plans, which are listed in the risk register (Mulcahy, 2010). To summarize the objectives of this process one by one, a long list can be provided which includes the following points:

- Implement the risk response plans, ensure compliance and manage process.
- Manage the contingency and management reserves.
- Create workarounds.
- Control the project risk.
- Refine and update the risk register.
- Perform additional risk identification, qualitative and quantitative risk analysis and risk response planning.
- Re-estimate the project.
- Keep stakeholders informed about the status of risks on the project (communicate about risks).
- Create lessons learned.
- Evaluate the risk impact of scope, schedule, cost and other change requests.

The following activities are part of the monitoring and controlling risks process: (Mulcahy, 2010)

- Managing the risk management plan and risk response plans.
- Watching for triggers.

- Keeping track of the identified risks.
- Managing the reserves.
- Ensuring the execution of the risk management plan and risk response plans.
- Dealing with risks that were not identified.
- Performing risk audits.
- Performing risk reviews.
- Coming up with additional risk response planning ideas.
- Taking corrective actions to adjust to the severity of actual risks.
- Revisiting non-top risks to see if the rankings of non-top or even top risks need to change or if risk responses need to be determined.
- Collecting and communicating risk status.
- Communicating with stakeholders about risks.
- Determining if assumptions are still valid.
- Looking for the any unexpected effects or consequences of risk events.
- Monitoring residual risks.
- Identifying new risks.
- Reviewing all workaround situations to see if they provide insight into the existence of additional risks.
- Updating the risk register.
- Making changes to the project management plan when new risk responses are developed.
- Creating a database of risk data that may be used throughout the organization on other projects.
- Recording results of team meetings and other meetings.
- Reviewing results from other projects not yet formalized into lessons learned.

- Re-evaluating risk identification, qualitative and quantitative risk analysis when the project deviates from the baseline.

2.6 Summary and Conclusions

In this chapter, the main concepts of the project risk management were explained in detail, and some of the most important international practices done so far in risk management of construction projects were introduced.

In order to prevent misunderstandings or confusions in the following parts of this thesis, the main terms of project risk management (such as “project”, “risk”, “risk management”, etc.) were precisely defined.

After an introduction to the main steps of the Risk Management Process (RMP), different available tools and techniques of risk identification and analysis were introduced and compared. In the following chapter, the chosen method will be described.

Chapter 3

METHODOLOGY

3.1 Introduction

In spite of the fact that the importance of RMP (Risk Management Process) is well known in Iranian construction industry, this process is not efficiently employed. Many improvements have to be done in this field, especially considering the significance of having a general efficient controlling system, on the project.

This research is mainly focusing on the managing process of steel-framed structures in Iranian construction projects. This type of buildings was chosen mainly due to their popularity and advantages. Risk management was planned to be studied for five stages of a construction work including earthwork, reinforcement, formwork, concrete work and steel structure, to develop the risk management successfully, by means of an appropriate method.

3.2 Research Method

The first stage of risk management, which is risk identification, will usually provide a long list of risks, like a checklist, which is indeed difficult to manage. Prioritizing these identified risks is a method employed to simplify their management by ordering them from the most critical to the least critical one. However, this arrangement will also not give a proper perspective about the structures of the risks (Hillson, 2002).

Structuring a large amount of data is always known to be the best method to deal with them and manage them. To do so, Risk Breakdown Structure (RBS) was employed to classify the identified potential risks into various levels. According to Hillson (2003), RBS is defined as a source oriented classification, which arranges and specifies the total level of project's risk exposure. A hierarchical structure is adopted by the method in which, each level shows more and more information about the risk sources.

It is worth explaining that risk management focuses on identification of work packages' risks and associated activities, besides the overall risk of the project (Mulcahy, 2010). Hence, projects' risks must be identified considering the area that the project is affected. Regarding this, WBS diagrams are handy tools that are hierarchical decomposition structure of a project tasks. They can be applied at diverse detail levels, i.e. project, tasks, etc., and establish the basic outlines of risk identification. Similar to WBS, RBS can be employed to arrange the identified risks (Hillson et al., 2006).

The methodology of this research work is based on combination of these two methods in order to generate efficient risk identification. To clarify more, a RBS is shown in Figure 3.1.

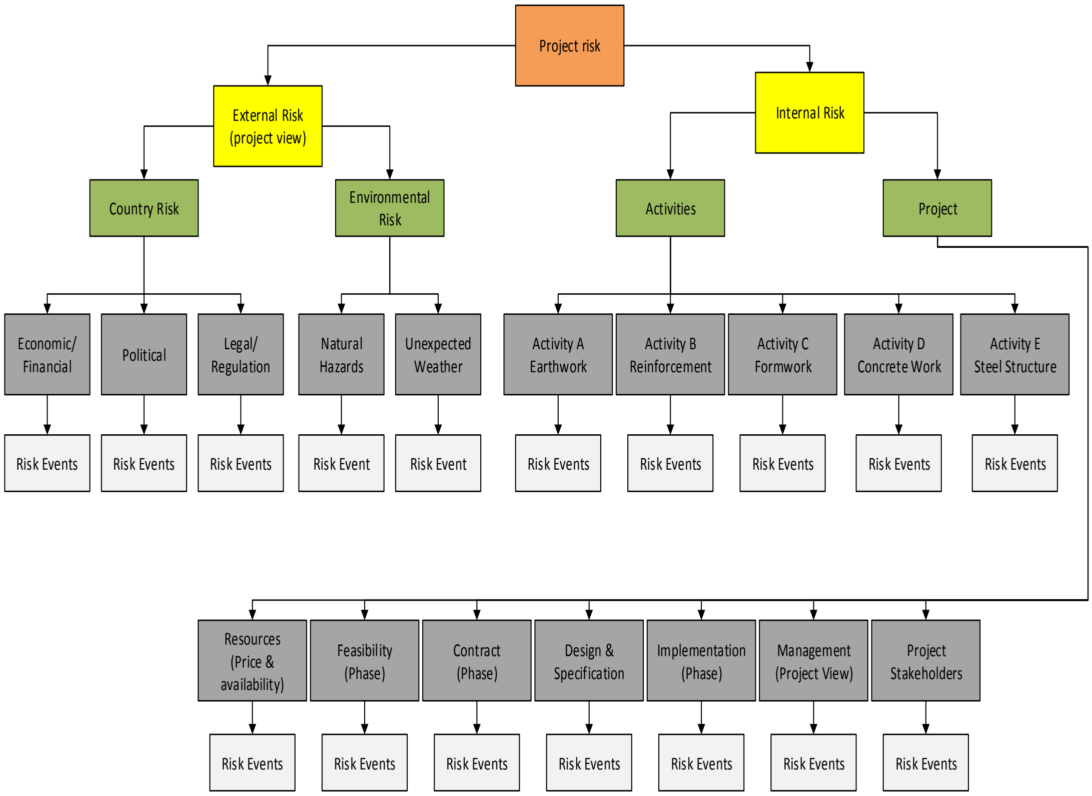

Figure 3.1: A risk Breakdown Structure

Generally, it seems that it is difficult to find an adequate method of risk assessment of the projects. However, these days, most of the construction companies are more motivated to perform qualitative analysis instead of quantitative analysis. The reason of this preference is the high time consumption of quantitative analysis, the fact that they need more sophisticated experts, to be performed truly and also they are not always required in risk management (Mulcahy, 2010).

It has been shown that qualitative analysis is more user-friendly, cost-effective and rapid compared to quantitative analysis (Banaitiene & Banaitis, 2012). Therefore in this research, qualitative analysis by means of probability and impact matrix has been chosen to be implemented.

Furthermore, checklist and questionnaire survey were chosen and designed as main data collection techniques.

The processes of these techniques are described in the next paragraphs.

3.3 The Process of Questionnaire Survey and Checklist

In the first step, a questionnaire including 24 questions was prepared to evaluate the knowledge of Iranian construction practitioners who participated in the survey, about concept of risk and risk management (A sample of the questionnaire is in Appendix A). In the second step, a checklist was prepared in 2 languages of English and Persian, which contains 105 identified risk events in different categories. The checklist also contains some columns for risk assessments and analyzing them. In the checklists, the participants were asked to score the potential risks' impact and occurrence probability, from 1 to 5 (See Appendix B). Furthermore, each risk's score is equal to the product of risk's impact and probability. In the procedure of risk management, arranging and categorizing the risks was done, based on the scores. Afterwards, these data were put in the matrix of probability and impact (PIM), in order to find the priority level of each identified risk and determine whether the risk is scored as high, moderate or low for that objective. The average risk scores and each risks percentages, total risk percentages, and the risks ratings are shown in the next chapters.

3.4 Risk Analysis: Qualitative Method with Probability and Impact Matrix

A checklist was sent to participants, aiming to concentrate on the identified risks, to assign a matrix of probability and impact.

The risks' occurrences probability, and their impacts on the project objectives, were evaluated by the survey participants. The employed scale to evaluate individual risks' levels of probability and impact on the four specific objectives is presented in, Table 3.1 that was adapted from the PMI (2013), PMI (2009), and HSE (2009).

Table 3.1: Defined conditions for probability and impact scales on major project objectives (PMI, 2013; HSE, 2009; PMI, 2009)

Scale	Probability	Impact on project objectives			
		Time	Cost	Quality	Health and Safety
Very High/ 5	61-99 %	> 20% time increase	> 40% cost increase	Project end item is effectively useless	Multiple deaths or sever permanent disablement
High/ 4	41-60 %	10 – 20% time increase	20 – 40% cost increase	Quality reduction unacceptable to sponsor	Death or extensive injuries
Moderate/ 3	21-40 %	5 – 10% time increase	10 – 20% cost increase	Quality reduction requires sponsor approval	Medical treatment required
Low/ 2	11-20 %	< 5% time increase	< 10% cost increase	Only very demanding applications	First aid treatment required
Very Low/ 1	1-10 %	Insignificant time increase	Insignificant cost increase	Quality degradation barely noticeable	No injury

As aforementioned, the likelihood and impact of the risks were scored, according to a proposed scale, from 1 to 5. In table 3.2, risks level are shown that was adapted from PMI (2013). Those risks, placed in the top right corner of matrix, are having the deepest negative impact, on the objectives (dark gray colored). The risks placed in bottom left corner, the medium gray colored cells, are the low impacting ones. Lastly, the light gray zone of matrix is including the moderate risks, that need to be focused, but they are not as essential as the highly impacting ones.

One of the benefits of this matrix is to simplify the decisions, against the evaluated risks.

Table 3.2: Probability and Impact Matrix (PMI, 2013)

Probability	Threats				
5/ Very High	5	10	15	20	25
4/ High	4	8	12	16	20
3/ Moderate	3	6	9	12	15
2/ Low	2	4	6	8	10
1/ Very Low	1	2	3	4	5
	1/ Very Low	2/ Low	3/ Moderate	4/ High	5/ Very High
	Impact				

Finally, the results were combined based on the probability and impact matrix. To arrange the crucial risks considering the project objectives, the outcomes will be presented separately in four different tables. The first one shows the most critical risks, which impacts on the objective of time, while the other tables are showing the identical results for the cost, quality and health and safety.

It is suggested that each organization should have an agreement on the interpretation of the risk matrices colors, and must have an established criteria and threshold to decide which risks are accepted, which ones are not and why (Flanagan & Norman, 1993).

3.5 Risk Response Planning Framework

The four most common actions which are mostly done against the potential identified risks (avoidance, mitigation, transfer and acceptance), were explained in the previous chapter, completely.

According to the PMBOK (2013) and Mulcahy (2010), high-risks located in dark gray area with the largest numbers in the probability and impact matrix, should definitely be moved into the plan risk responses process. Moreover, moderate risks which will be located in the light gray area, with intermediate numbers, require management, control, and attention, and might be decided to be moved into the plan risk responses process. Finally, low-risks which are displayed in the medium gray color, with the smallest numbers, are risks that can be accepted, without further investigations or responses and simply be documented.

This research will consider risk responses, only for risks with high exposure (high-risks) on project objectives (time, cost, quality and health and safety).

In the next chapter, data collections, analysis and explanations will be presented about the chosen methodology, and methods of adopting it, in this research work.

Chapter 4

DATA COLLECTION AND ANALYSIS

4.1 Introduction

This chapter is mainly about presenting the collected data, which were gathered by means of checklists. Checklists were chosen to be the data collecting tool, because of the fact that the objective of this research is to find the likelihood and the effect of each identified risk on the project objectives, and to understand how risk management techniques work. Especially according to PMI (2013), employment of checklists to collect data is a suitable and quick method for descriptive determinations.

The potential risks that have been identified according to various viewpoints of participants in the survey have been summarized and presented in this chapter.

4.2 Checklist

Iran is known to be a developing country, with a wide range of valuable natural resources and therefore, it has a great potential for attracting investors to different sectors, among which the construction sector is known to be a key sector. Not surprisingly, due to high potential risks associated with this sector, construction companies face with various types of risks and have to employ applicable methods and techniques to manage the risks.

However, unfortunately due to lack of adequate information in this field, except for a few ones, a large portion of Iranian companies have not paid enough attention to the importance of risk management which is going to be the main discussed topic in this research.

To obtain a better knowledge of how the Iranian contractors perform the process of risk management, 35 members of top Iranian construction companies were chosen and asked to participate in the survey. All of the chosen companies were confirmed by Iranian Central Building and Construction Engineering Organization and prepared checklists and questionnaires were distributed among their members, which afterwards, it was found that their average job experience is 16 years.

Among the total number of companies (35), 20 of them participated and answered the questionnaires and checklists, and 15 of them did not, which means that totally, there are 20 valid checklists. The average response rate was found to be 57.1%. Table 4.1 shows checklist description and respondent’s profile. In Appendix E, there are more detailed information about the participants’ names, job experiences, their company names, and etc.

Table 4.1: Respondent Profile and Checklist Explanation

Total Number of Checklist and Questionnaire	35
Total Number of Valid Checklist and Questionnaire	20
Total Response Rate (%)	57.1
Average Job Experience (Years)	16
Total Number of Project Managers	5
Total Number of Site Supervisors	4
Total Number of Consultants	3
Total Number of Structural Engineers	3
Total Number of Site Managers	2
Total Number of Executive Directors	2
Total Number of Technical Office Engineer	1

4.3 Analysis and Results

4.3.1 Risk Identification

As explained previously, various approaches can be employed to identify the risk in different projects. Between the methods, using checklists and reverting to the recorded historical data are known to be more popular in construction projects' risk management performance, especially that they are very useful in methods documentation. Besides these, negotiations and referring to the experiences are also performed to gather information.

Table 4.2 shows the results of the checklists consisting the most important identified risks, which are commonly occurring in Iran. These risks have been prepared in the form of a checklist to find out more about the first step of risk management. Also, all the reliabilities were evaluated by means of SPSS software. Appendix I shows the SPSS assessment results. It is worth mentioning that there were also different methods of identifying risks between the team members of the projects.

Table 4.2: The most important identified risks with their Risk Breakdown Structures

Risk Analysis (RBS &WBS)				
Risk Categories				Risk Events
Level 0	Level 1	Level 2	Level 3	
			Feasibility(Phase)	Unavailability of needed information,code and standards.
				Litigation conflict with neighbor of the project.
				Project Funding difficulties due to bad financial situation of financier (s).
				Delay of bank in project fund allocation.
				Poor or incorrect estimation in market,technical & financial analysis.
				Poor preliminary assessment and evaluation of different possibilities of treatment measures for ground and groundwater.
			Contract (Phase)	Delay in contract issue by owner of the project.
				Inconsistency or mistake in contract documents.
				Any problem or conflict of contractor(s),subcontractor (s),owner (s),project manager and all the stakeholders with contract.
				Allocation of risks to the contractor (s),subcontractor (s),owner (s),consultant(s),desiner(s),etc is not mentioned or is not clear in the contract.
				Non standard or inappropriate contract form (type or form of the contract is not standard or compatible with laws).
			Design & Specification	The lack of a precise definition of the project and defects in the project documents such as project charter,project scope statement,etc.
				Lack of consistency between bill of quantities ,drawings and specifications.
				Inaccurate or incorrect estimation of time,cost and resources in accordance with WBS.
				Incompatibility of architectural, structural and mechanical,etc plans (Not coordinated design).
				Poor or incorrect technical design due to incorrect or insufficient available information (geological ,geotechnical,..).
				Design is not appropriate with the project objectives or requirement of the project.
				Incorrect or insufficient design data.
				Change in design due to change in design standards during design process.
				Mistake of designer (s) in calculations ,analysis and evaluations.
				Delay in presenting design results or design drawing.

Project Risk	Internal Risk	Project	Resources (Price & Availablity & Quality)	Unavailability (lack)or high price of needed equipments due to economic conditions in project region or country.
				Unavailability (lack)or high price of manpower due to economic conditions in country.
				Unavailability (lack)or high price of materials due to economic conditions in project region or country.
				Poor quality of needed materials,equipment,contractor(s) and subcontractor(s) in project region.
				Unavailability or lack of needed experts , professional managers and experienced contractors in project region.
			Management (Project view)	Poor communication in project between different stakeholders.
				Any problem related to poor monitoring and controlling the quality of tasks execution in project.
				Any change in management strategies, principles or change of manager(s) of the project,owner(s) and general contractor(s).
				Applied schedule by inexperienced project manager is not consistent with the desired cost ,scope and quality of the project (inconsistent cost ,time,scope and quality objectives) .
				Damage to persons, properties and materials due to poor health and safety management of the project.
				Schedule compression techniques such as fast tracking and crashing may result in increased risk.
				Lack of consideration of contingency reserve and management reseve in estimating cost and time of the project to encounter with known-unknown and unknown-unknown risks.
				The project organization chart has not sufficient detail to identify the key personnel and their roles and responsibilities.
				Scope creep.
			Implementation	Delay in payment to contractor(s) during project implementation phase.
				Strike during implementation phase.
				Delay of contractor in final billing presentation due to poor performance of personnel.
				Irregular or inadequacy of site inspection by consultant(s) during implementation phase.
				Any problem due to poor inspection of work by contractor (Technical mistakes ,etc)during implementation phase.
			Project Stakeholders	Skill deficiency of project manager(s),contactor(s),subcontractor(s),owner(s),consultant(s) ,etc in internal management.
				Delay in approving the contractor(s) work by consultant(s) or owner(s) of the project.
				Incompetency of contractor/subcontractor due to lack of experience,equipments ,enough qualified experts and labors.
				Any problems and conflict between different partners of the project.
				Financial difficulties of contractor(s) and owner(s) of the project (Problems to provide project funds on time) .
				Late design variations by owner(s) of the project or late changes requested by stakeholders .
				Delay in decision making of the project by inexperienced owner(s).
				Project manager and functional manager(s) to resign.
				Delay in materials deliveries by suppliers (Supplier's incompetency to deliver materials on time).

		Activities	Activity A (Earth work)	Adjacent structures collapse (Collapse of neighbouring buildings) due to inadequate retaining walls.
				Landslides due to hard rains during excavation phase which may lead to collapse of neighbouring buildings.
				Ground collapse.
				Collapse of excavation sides due to instability of excavation.
				A person being trapped by the collapse of an excavation.
				Excavation machinery falls from unprotected edges (Machinery crashes).
				Manpower's falling into an excavation.
				Contact with underground cables (essential services)and cutting them during excavation phase.
				Exposure to underground water during excavation.
			Activity B (Reinforcement)	Injuries from worker's stumble and falling on the exposed steel rebars (Protruding rebar ends).
				Heavy lifting of rebar is a potential risk factor.
				Corrosion of steel rebars.
				Injuries from cutting and bending rebar.
				Manpower's slip and fall into reinforcement mesh (Slips & Trips).
				Manpower's damage by reinforcement wire and rebar 's sharp edges .
				Back bending and high hand force with repetition and awkward posture while tying rebars.
			Activity C (Formwork)	Formwork collapse during and after pouring concrete due to inadequate support and low strength to stand the pressure or weight of fresh concrete and vibration pressure,etc.
				Falling objects from height.
				Manpower's falling from edges of formwork frames during their erection.
				Safe working load exceeded during lifting equipments and materials such as lumber,plywood,forms ,etc (Heavy lifting).
				Deflection of slab after pouring concrete due to inadequate and inappropriate props installations,etc.
				Injury from manually handling the form ply sheets.
				Collapse of slab due to early removal of the forms,props,etc.
				Injury of worker's due to slip onto form ply sheet (Slips & Trips).
			Activity D (Concrete Work)	Collapse of fresh concrete container (bucket,barrow,etc.) during pouring operations.
				Delay in delivery of ready mixed concrete during pouring concrete.
				Failure of support systems or platform during pouring concrete.
				Concrete cracks (Types of concrete cracks such as shrinkage crack,Tension crack ,etc).
				Contact of wet concrete with eyes and skin during pouring concrete.
				Manpower's falling down from openings or void spaces&ducts and edge of the work area .
				Back bending due to hand troweling and manual screeding during pouring concrete (Slab & Foundation).
				Being struck by objects (equipment & materials) such as concrete buckets.chutes,etc.

			Activity E (Steel Structure)	Instability and collapse of structure due to inadequate temporary bracing during steelwork.
				Collapse of structure due to inappropriate and poor welding of joints (between column,beam and bracing) during erection.
				Failure of lifting equipments.
				Being struck by objects such as steel members (fall of construction materials and tools)
				Probability of fire due to welding operation(Welding spatter,grinding spark in flammable environment).
				Injury of third parties and workers during steel structure erection.
				Crane overturn due to overloading.
				Manpower's falling from the height during erection of steel structure.
				Collapse of structure due to members failure from temprary loading (Unexpected heavy winds) during erection.
				Crane slings or chains may be released during erection steel structure erection (columns,beams,etc.)
				Weld failure due to poor quality or lack of testing.
				Fabrication errors (angles,etc.) and incomplete fabrication (missing components).
	External Risk (Project View)	Environmental Risk	Unexpected Weather	Any unwanted weather conditions such as very cold,very hot,windy,rainy weather and snowy weather .
			Natural Hazards	Natural disasters such as earthquake,flood,landslide,fire,storm and glacial weather,etc.
		Country Risk	Economic & Financial	Market fluctuations (Low market demand , change in market demand ,etc).
				Inflation rate unpredictably increasing.
				Economic slowdown or economic crisis .
				Interest rate fluctuation.
				Exchange rate fluctuation.
			Political	Any change in political situation such as sanction,etc.
				Political conflict with other countries.
			Legal & Regulation	Unwanted changes in laws and standards.
				Delay of government to issue the project permissions (Requirement for permits and their approval take longer than expected).

4.3.2 Risk Analysis

In this stage of risk management process, as mentioned before, to evaluate the identified risks, qualitative methods were employed because of their advantages comparing to the quantitative ones. It is shown that various methods are being employed to rank the risks, when analysis are performed. Nevertheless, most of the companies (participants in the survey), preferred to refer to the previous employed techniques and actually, except six companies, the others did not have any knowledge or experience about a structured risk management technique.

However, it was also found out that many companies were managing and dealing with different risks successfully without employing any organized risk management method, but by following their own acknowledged methods. These methods also have been decided to be approached by well-structured risk management methods. To do this, probability and impact matrix and qualitative methods were employed.

The results of risk identification were prioritized; the average risk scores and each risks percentages, as well as the total risk percentages and the risks ratings based on average risk scores of each objectives are shown in Tables 4.3, 4.4, 4.5, 4.6 and 4.7 separately.

Moreover, the general risk score, based on cumulative score of the projects' objectives and the general ranking of risks are available in Tables 4.3 and 4.8. Moreover, Figure 4.26 indicates the total percentages of risks compared to each other.

The risk significant index was used in this research, established by (Shen, et al., 2001).

Considering the effectiveness of risks on specific project objectives, the significance score, evaluated by each respondent can be calculated by Equation (1).

$$r_{ij}^{k} = \alpha_{ij}\beta_{ij}^{k} \qquad \text{(Eq.1)}$$

In which; *r* is the significance score of risk *i*, evaluated by respondent *j*, on the project objective *k* ; *k* is the ordinal number of project objective, varying between 1 to 4; *i* is the ordinal number of risk, varying between 1 to 105 and *j* is the ordinal number of valid feedback to risk *i*, *j*= (1, *n=20*); *n* = total number of valid checklists*; β* = level of impact of risk *i* on project objective *k*, assessed by respondent *j and α* = likelihood occurrence of risk *i*, assessed by respondent *j;*

The average score of each risk considering its impact on a specific project objective, can be calculated by Equation (2).

This average score is called the risk significance index score, and will be employed to arrange all risks impacts, on a particular project objective.

$$R_{i}^{k} = \frac{\sum_{j=1}^{n} r_{ij}^{k}}{n} = \frac{1}{n}\sum_{j=1}^{n} \alpha_{ij}\beta_{ij}^{k} \qquad \text{(Eq.2)}$$

In which *R* is the significance index score for risk *i* on project objective *k.* (Average risk score for risk *i* on project objective *k*). The complete calculation process is available in Appendix F.

Table 4.3: Identified risks arrangement

No.	Risk Events	Average Risk Score	Percent of each risk (%)	Total Percent of risks (%)	Average Risk Score	Percent of each risk (%)	Total Percent of risks (%)	Average Risk Score	Percent of each risk (%)	Total Percant of risks (%)	Average Risk Score	Percent of each risk (%)	Total Percent of risks (%)	Risk Score	Total Percentage Risk Score (%)
		Time			Cost			Quality			Health & Safety			Overall	
1	Unavailability of needed information,code and standards.	5.3	0.6157		4.95	0.5554		5.4	0.7465		6.55	1.1594		5.452925	0.6973496
2	Litigation conflict with neighbor of the project.	5.8	0.6738		2.95	0.331		2.7	0.3732		3.15	0.5576		3.734225	0.4775529
3	Project Funding difficulties due to bad financial situation of financier (s).	9.55	1.1095		6	0.6732		5.45	0.7534		3.3	0.5841		6.3719	0.8148731
4	Delay of bank in project fund allocation.	6	0.6971		8.9	0.9987		5	0.6912		4.05	0.7169		6.24918	0.799179
5	Poor or incorrect estimation in market,technical & financial analysis.	11.1	1.2896		10.75	1.2062		6.7	0.9262		3.25	0.5753		8.491015	1.085877
6	Poor preliminary assessment and evaluation of different possibilities of tr	8.65	1.0049		10.15	1.1389		5.3	0.7327		3.9	0.6903		7.40927	0.9475376
7	Delay in contract issue by owner of the project.	12.4	1.4406		9.4	1.0548		3.75	0.5184		3.2	0.5664		7.752265	0.9914016
8	Inconsistency or mistake in contract documents.	11.9	1.3825		15.15	1.7		11.65	1.6105		4.45	0.7877		11.4077	1.4588784
9	Any problem or conflict of contractor(s),subcontractor (s),owner (s),proje	8.1	0.941		8.5	0.9538		7.8	1.0782		4.15	0.7346		7.41115	0.947778
10	Allocation of risks to the contractor (s),subcontractor (s),owner (s),consultant(s),desiner(s),etc is not mentioned or is not clear in the contract.	14.4	1.673		18.65	2.0927		13.75	1.9007		4.8	0.8496		13.70592	1.7527873
11	Non standard or inappropriate contract form (type or form of the contract	6.95	0.8074		6.8	0.763		5.25	0.7257		3.35	0.593		5.83203	0.7458316
12	The lack of a precise definition of the project and defects in the project documents such as project charter,project scope statement,etc.	14.9	1.731		14.1	1.5821		13.15	1.8178		4.3	0.7611		12.278225	1.5702059
13	Lack of consistency between bill of quantities ,drawings and specificatio	8.9	1.034		7.4	0.8303		7.75	1.0713		3.1	0.5487		7.108235	0.9090396
14	Inaccurate or incorrect estimation of time,cost and resources in accordan	19.9	2.3119		18.6	2.0871		18.2	2.5159		5.7	1.0089		16.47419	2.1068086
15	Incompatibility of architectural, structural and mechanical,etc plans (Not	17.1	1.9866		16.45	1.8458		17.3	2.3915		4.8	0.8496		14.670015	1.876081
16	Poor or incorrect technical design due to incorrect or insufficient availabl	7.45	0.8655		7.5	0.8416		7.35	1.016		4.6	0.8142		6.91059	0.8837637
17	Design is not appropriate with the project objectives or requirement of th	4.05	0.4705		4.45	0.4993		4.25	0.5875		1.9	0.3363		3.814945	0.4878758
18	Incorrect or insufficient design data.	16.25	1.8879		16.7	1.8739		16.5	2.2809		4.1	0.7257		14.182275	1.8137061

19	Change in design due to change in design standards during design proce	7	0.8132		7	0.7855		5.25	0.7257		2.85	0.5045		5.811905	0.7432579
20	Mistake of designer (s) in calculations ,analysis and evaluations.	8.95	1.0398		8.85	0.993		9.05	1.251		3.4	0.6018		7.912395	1.0118799
21	Delay in presenting design results or design drawing.	8.35	0.9701		5.65	0.634		3.55	0.4907		2.75	0.4868		5.375395	0.6874346
22	Unavailability (lack)or high price of needed equipments due to economic	6.2	0.7203		5.2	0.5835		5.55	0.7672		2.3	0.4071		5.027025	0.6428832
23	Unavailability (lack)or high price of manpower due to economic conditior	6.3	0.7319		6.4	0.7181		5.45	0.7534		2.35	0.416		5.392555	0.6896291
24	Unavailability (lack)or high price of materials due to economic conditions	17.1	1.9866		18.7	2.0983		15.4	2.1288		4.25	0.7523		14.77529	1.8895441
25		5.95	0.6913		5.9	0.662		7.05	0.9746		4.85	0.8585		5.99206	0.7662971
26	Unavailability or lack of needed experts , professional managers and expe	4.4	0.5112		4.85	0.5442		4.15	0.5737		2.9	0.5133		4.19328	0.5362594
27	Poor communication in project between different stakeholders.	5.65	0.6564		5.45	0.6115		6.1	0.8432		2.55	0.4514		5.12189	0.655015
28	Any problem related to poor monitoring and controlling the quality of tas	15.35	1.7833		17.75	1.9917		16.85	2.3293		8.9	1.5754		15.210345	1.9451813
29	Any change in management strategies, principles or change of manager(s	4.4	0.5112		4.5	0.5049		3.85	0.5322		3.55	0.6284		4.140095	0.5294578
30	Applied schedule by inexperienced project manager is not consistent with the desired cost ,scope and quality of the project (inconsistent cost ,time,scope and quality objectives) .	10.1	1.1734		10.55	1.1838		8	1.1059		5.05	0.8939		8.793005	1.1244971
31	Damage to persons, properties and materials due to poor health and safet	8.35	0.9701		7.4	0.8303		6.05	0.8363		11.05	1.9559		8.02521	1.0263073
32	Schedule compression techniques such as fast tracking and crashing may	7.65	0.8888		10.15	1.1389		7.35	1.016		5.35	0.947		7.883275	1.0081559
33	Lack of consideration of contingency reserve and management reseve in estimating cost and time of the project to encounter with known-unknown and unknown-unknown risks.	12.9	1.4987		15.75	1.7673		12.75	1.7625		5.3	0.9381		12.28628	1.571236
34	The project organization chart has not sufficient detail to identify the key	3.5	0.4066	28.311	3.45	0.3871	29.313	2.05	0.2834	23.794	2.45	0.4337	18.582	2.94495	0.3766162
35	Scope creep.	5.85	0.6796		5.85	0.6564		5.05	0.6981		2.95	0.5222		5.120275	0.6548085
36	Delay in payment to contractor(s) during project implementation phase.	16.65	1.9344		16.25	1.8234		14.25	1.9699		5.15	0.9116		13.823435	1.7678157
37	Strike during implementation phase.	3.1	0.3602		3.2	0.3591		3.1	0.4285		3.5	0.6195		3.20332	0.4096579
38	Delay of contractor in final billing presentation due to poor performance c	5.4	0.6274		5.55	0.6228		4.95	0.6843		2.7	0.4779		4.83471	0.6182889
39	Irregular or inadequacy of site inspection by consultant(s) during implem	4.75	0.5518		4.45	0.4993		3.95	0.546		3.6	0.6372		4.257605	0.5444856
40	Any problem due to poor inspection of work by contractor (Technical mi	16.5	1.9169		16.35	1.8346		16.55	2.2878		8.5	1.5046		14.97988	1.9157082

41	Skill deficiency of project manager(s),contactor(s),subcontractor(s),owner	4.6	0.5344	4.8	0.5386	5	0.6912	4.7	0.8319	4.7719	0.6102564
42	Delay in approving the contractor(s) work by consultant(s) or owner(s) of	5.95	0.6913	6.45	0.7237	3.45	0.4769	2.4	0.4248	4.841615	0.6191719
43	Incompetency of contractor/subcontractor due to lack of experience,equip	9.75	1.1327	9.9	1.1109	7.7	1.0644	8.1	1.4338	8.998725	1.1508057
44	Any problems and conflict between different partners of the project.	12	1.3941	12.1	1.3577	12.45	1.721	5.1	0.9027	10.853145	1.3879589
45	Financial difficulties of contractor(s) and owner(s) of the project (Problem	17.55	2.0389	17.7	1.9861	16.95	2.3431	11	1.9471	16.23248	2.0758974
46	Late design variations by owner(s) of the project or late changes requeste	17.9	2.0796	15.55	1.7448	12.8	1.7694	4.6	0.8142	13.524995	1.7296496
47	Delay in decision making of the project by inexperienced owner(s).	9.75	1.1327	7.4	0.8303	4.6	0.6359	2.95	0.5222	6.571615	0.8404137
48	Project manager and functional manager(s) to resign.	7.25	0.8423	7	0.7855	6.55	0.9054	3.6	0.6372	6.3313	0.8096809
49	Delay in materials deliveries by suppliers (Supplier's incompetency to del	16.4	1.9053	16	1.7953	9.5	1.3132	5.05	0.8939	12.53078	1.602504
50	Adjacent structures collapse (Collapse of neighbouring buildings) due t	17.7	2.0563	17.5	1.9636	12.15	1.6796	18	3.1861	16.375005	2.0941243
51	Landslides due to hard rains during excavation phase which may lead to c	6.3	0.7319	7.15	0.8023	4.65	0.6428	6.6	1.1682	6.21171	0.7943871
52	Ground collapse.	5.15	0.5983	4.95	0.5554	3.45	0.4769	6	1.062	4.844365	0.6195236
53	Collapse of excavation sides due to instability of excavation.	4.3	0.4996	4.8	0.5386	3	0.4147	4.5	0.7965	4.17401	0.533795
54	A person being trapped by the collapse of an excavation.	4.2	0.4879	4.95	0.5554	1.8	0.2488	5.15	0.9116	4.024955	0.514733
55	Excavation machinery falls from unprotected edges (Machinery crashes).	5.65	0.6564	6.85	0.7686	4.25	0.5875	6.25	1.1063	5.779575	0.7391233
56	Manpower's falling into an excavation.	4.65	0.5402	4.75	0.533	1.75	0.2419	5.2	0.9204	4.091125	0.5231952
57	Contact with underground cables (essential services)and cutting them d	16.15	1.8763	15.45	1.7336	7.9	1.0921	7.2	1.2744	12.31763	1.5752452
58	Exposure to underground water during excavation.	3.6	0.4182	4.1	0.4601	2.6	0.3594	1.8	0.3186	3.17385	0.4058891
59	Injuries from worker's stumble and falling on the exposed steel rebars (Pr	5.05	0.5867	7.2	0.8079	4.3	0.5944	10.65	1.8851	6.541715	0.8365899
60	Heavy lifting of rebar is a potential risk factor.	2.55	0.2963	2.5	0.2805	1.95	0.2696	4.15	0.7346	2.68963	0.3439644
61	Corrosion of steel rebars.	2.8	0.3253	3	0.3366	5	0.6912	2.3	0.4071	3.28882	0.4205921
62	Injuries from cutting and bending rebar.	2.8	0.3253	2.8	0.3142	2.55	0.3525	3.15	0.5576	2.805275	0.3587538
63	Manpower's slip and fall into reinforcement mesh (Slips & Trips).	2.45	0.2846	3.05	0.3422	2.2	0.3041	4.1	0.7257	2.87271	0.3673777
64	Manpower's damage by reinforcement wire and rebar 's sharp edges .	5.6	0.6506	6.1	0.6845	3.6	0.4976	5.75	1.0178	5.29806	0.6775446
65	Back bending and high hand force with repetition and awkward posture w	2.85	0.3311	3.6	0.4039	2.3	0.3179	4.25	0.7523	3.198815	0.4090818

66	Formwork collapse during and after pouring concrete due to inadequate support and low strength to stand the pressure or weight of fresh concrete and vibration pressure,etc.	15.8	1.8356		12.7	1.425		15.2	2.1012		8	1.4161		13.29783	1.7005985
67	Falling objects from height.	5.65	0.6564		7.8	0.8752		4.05	0.5599		8.65	1.5311		6.45636	0.8256743
68	Manpower's falling from edges of formwork frames during their erection.	5.3	0.6157		6.4	0.7181		2.45	0.3387		7.6	1.3453		5.371205	0.6868988
69	Safe working load exceeded during lifting equipments and materials such	3.85	0.4473		6	0.6732		2.7	0.3732		6.3	1.1151		4.661405	0.5961257
70	Deflection of slab after pouring concrete due to inadequate and inappropr	13.45	1.5626		14.1	1.5821		17.15	2.3707		8.05	1.4249		13.51608	1.7285095
71	Injury from manually handling the form ply sheets.	2.5	0.2904		3.2	0.3591		2.5	0.3456		3.95	0.6992		2.97433	0.3803734
72	Collapse of slab due to early removal of the forms,props,etc.	7.2	0.8365		6.95	0.7798		5.5	0.7603		7.35	1.301		6.749445	0.8631556
No.	**Risk Events**	Average Risk Score	Percentage of each risk (%)	Total Percentage of risks (%)	Average Risk Score	Percentage of each risk (%)	Total Percentage of risks (%)	Average Risk Score	Percentage of each risk (%)	Total Percentage of risks (%)	Average Risk Score	Percentage of each risk (%)	Total Percentage of risks (%)	Risk Score	Total Percentage Risk Score (%)
		Time			Cost			Quality			Health & Safety			Overall	
73	Injury of worker's due to slip onto form ply sheet (Slips & Trips).	4.7	0.546		4.15	0.4657		3.55	0.4907		6.35	1.124		4.57131	0.5846039
74	Collapse of fresh concrete container (bucket,barrow,etc.) during pouring c	3.25	0.3776		3.9	0.4376		3.4	0.47		5.9	1.0443		3.968245	0.5074807
75	Delay in delivery of ready mixed concrete during pouring concrete.	6.7	0.7784		6.55	0.735		7.7	1.0644		4.3	0.7611		6.447345	0.8245214
76	Failure of support systems or platform during pouring concrete.	6.15	0.7145		7.05	0.7911		7.35	1.016		6.7	1.1859		6.800845	0.8697289
77	Concrete cracks (Types of concrete cracks such as shrinkage crack,Tens	8.65	1.0049		10.45	1.1726		11.25	1.5552		6.3	1.1151		9.358625	1.1968316
78	Contact of wet concrete with eyes and skin during pouring concrete.	2.8	0.3253		3	0.3366		3.3	0.4562		3.95	0.6992		3.19096	0.4080772
79	Manpower's falling down from openings or void spaces&ducts and edge	5.35	0.6216		6.6	0.7406		2.55	0.3525		6.8	1.2036		5.31913	0.6802391
80	Back bending due to hand troweling and manual screeding during pourin	6	0.6971		5.35	0.6003		4.15	0.5737		5.45	0.9647		5.26658	0.6735188
81	Being struck by objects (equipment & materials) such as concrete bucket	2.8	0.3253		5.2	0.5835		2.15	0.2972		5.1	0.9027		3.775865	0.4828781
82	Instability and collapse of structure due to inadequate temporary bracing	16.1	1.8705		15.2	1.7056		10.25	1.4169		16.1	2.8498		14.442885	1.8470343
83	Collapse of structure due to inappropriate and poor welding of joints (bet	13.6	1.58		13.25	1.4868		13.7	1.8938		13.45	2.3807		13.491975	1.7254268
84	Failure of lifting equipments.	4.45	0.517		4.6	0.5162		3.05	0.4216		6.05	1.0709		4.45774	0.5700799

85	Being struck by objects such as steel members (fall of construction mater	5.1	0.5925		9.95	1.1165		5.2	0.7188		8.4	1.4869		7.157955	0.915398
86	Probability of fire due to welding operation(Welding spatter,grinding spar	4.35	0.5054		4.5	0.5049		3	0.4147		5.1	0.9027		4.211715	0.5386169
87	Injury of third parties and workers during steel structure erection.	3.3	0.3834		6.2	0.6957		2.35	0.3249		5.85	1.0355		4.397445	0.5623691
88	Crane overturn due to overloading.	4.45	0.517		4.5	0.5049		2.65	0.3663		4.55	0.8054		4.05457	0.5185204
89	Manpower's falling from the height during erection of steel structure.	4.85	0.5635	28.311	7.9	0.8864	29.313	1.85	0.2557	23.794	8.25	1.4603	18.582	5.66149	0.724022
90	Collapse of structure due to members failure from temprary loading (Unex	6	0.6971		7.25	0.8135		3	0.4147		7.6	1.3453		5.949355	0.7608357
91	Crane slings or chains may be released during erection steel structure ere	3.45	0.4008		3.7	0.4152		3.05	0.4216		5	0.885		3.71576	0.4751915
92	Weld failure due to poor quality or lack of testing.	7.25	0.8423		7.5	0.8416		7.1	0.9815		4	0.708		6.683015	0.8546601
93	Fabrication errors (angles,etc.) and incomplete fabrication (missing comp	14.7	1.7078		14.9	1.6719		15.55	2.1496		6.45	1.1417		13.426515	1.7170554
94	Risk of injury from inhalation of toxic gases generated during welding.	2.2	0.2556		2.9	0.3254		2.3	0.3179		2.95	0.5222		2.56809	0.3284213
95	Any unwanted weather conditions such as very cold,very hot,windy,rain	18.15	2.1086		18.25	2.0478		14.3	1.9768		10.1	1.7878		15.76589	2.0162274
96	Natural disasters such as earthquake,flood,landslide,fire,storm and glacial	6.55	0.761		6	0.6732		6.35	0.8778		6.9	1.2213		6.40559	0.8191815
97	Market fluctuations (Low market demand , change in market demand ,etc)	8.85	1.0282		9.4	1.0548		6.5	0.8985		4.85	0.8585		7.708055	0.9857478
98	Inflation rate unpredictably increasing.	13.5	1.5684		16.65	1.8683		13.7	1.8938		7.95	1.4072		13.438305	1.7185632
99	Economic slowdown or economic crisis .	11.8	1.3709		12.5	1.4026		6.8	0.94		4.9	0.8673		9.53247	1.2190639
100	Interest rate fluctuation.	3.05	0.3543		4.2	0.4713		3.1	0.4285		2.25	0.3983		3.250015	0.4156295
101	Exchange rate fluctuation.	6.9	0.8016		7.95	0.8921		6.95	0.9607		5.1	0.9027		6.88452	0.8804297
102	Any change in political situation such as sanction,etc.	16.4	1.9053		16.3	1.829		18.65	2.5781		8.6	1.5223		15.455085	1.97648
103	Political conflict with other countries.	3.9	0.4531		3.1	0.3478		3.9	0.5391		2.25	0.3983		3.35856	0.4295108
104	Unwanted changes in laws and standards.	6.1	0.7087		5.45	0.6115		5.8	0.8018		3.4	0.6018		5.335845	0.6823768
105	Delay of government to issue the project permissions (Requirement for p	9.55	1.1095		7.4	0.8303		3.35	0.4631		2.7	0.4779		6.17117	0.7892026
Sum		860.75	100	28.311	891.2	100	29.313	723.4	100	23.794	564.95	100	18.582	781.95362	100

Table 4.4: Identified risks rankings, considering time

No.	Risk Events	Risk Rating Time
1	Inaccurate or incorrect estimation of time,cost and resources in accordance with WBS.	19.9
2	Any unwanted weather conditions such as very cold,very hot,windy,rainy weather and snowy weather .	18.15
3	Late design variations by owner(s) of the project or late changes requested by stakeholders .	17.9
4	Adjacent structures collapse (Collapse of neighbouring buildings) due to inadequate retaining walls.	17.7
5	Financial difficulties of contractor(s) and owner(s) of the project (Problems to provide project funds on time) .	17.55
6	Incompatibility of architectural, structural and mechanical,etc plans (Not coordinated design).	17.1
7	Unavailability (lack)or high price of materials due to economic conditions in project region or country.	17.1
8	Delay in payment to contractor(s) during project implementation phase.	16.65
9	Any problem due to poor inspection of work by contractor (Technical mistakes ,etc)during implementation phase.	16.5
10	Delay in materials deliveries by suppliers (Supplier's incompetency to deliver materials on time).	16.4
11	Any change in political situation such as sanction,etc.	16.4
12	Incorrect or insufficient design data.	16.25
13	Contact with underground cables (essential services)and cutting them during excavation phase.	16.15
14	Instability and collapse of structure due to inadequate temporary bracing during steelwork.	16.1
15	Formwork collapse during and after pouring concrete due to inadequate support and low strength to stand the pressure or weight of fresh concrete and vibration pressure,etc.	15.8
16	Any problem related to poor monitoring and controlling the quality of tasks execution in project.	15.35
17	The lack of a precise definition of the project and defects in the project documents such as project charter,project scope statement,etc.	14.9
18	Fabrication errors (angles,etc.) and incomplete fabrication (missing components).	14.7
19	Allocation of risks to the contractor (s),subcontractor (s),owner (s),consultant(s),desiner(s),etc is not mentioned or is not clear in the contract.	14.4
20	Collapse of structure due to inappropriate and poor welding of joints (between column,beam and bracing) during erection.	13.6
21	Inflation rate unpredictably increasing.	13.5

22	Deflection of slab after pouring concrete due to inadequate and inappropriate props installations,etc.	13.45
23	Lack of consideration of contingency reserve and management reseve in estimating cost and time of the project to encounter with known-unknown and unknown-unknown risks.	12.9
24	Delay in contract issue by owner of the project.	12.4
25	Any problems and conflict between different partners of the project.	12
26	Inconsistency or mistake in contract documents.	11.9
27	Economic slowdown or economic crisis .	11.8
28	Poor or incorrect estimation in market,technical & financial analysis.	11.1
29	Applied schedule by inexperienced project manager is not consistent with the desired cost ,scope and quality of the project (inconsistent cost ,time,scope and quality objectives) .	10.1
30	Incompetency of contractor/subcontractor due to lack of experience,equipments ,enough qualified experts and labors.	9.75
31	Delay in decision making of the project by inexperienced owner(s).	9.75
32	Project Funding difficulties due to bad financial situation of financier (s).	9.55
33	Delay of government to issue the project permissions (Requirement for permits and their approval take longer than expected).	9.55
34	Mistake of designer (s) in calculations ,analysis and evaluations.	8.95
35	Lack of consistency between bill of quantities ,drawings and specifications.	8.9
36	Market fluctuations (Low market demand , change in market demand ,etc).	8.85
37	Poor preliminary assessment and evaluation of different possibilities of treatment measures for ground and groundwater.	8.65
38	Concrete cracks (Types of concrete cracks such as shrinkage crack,Tension crack ,etc).	8.65
39	Delay in presenting design results or design drawing.	8.35
40	Damage to persons, properties and materials due to poor health and safety management of the project.	8.35
41	Any problem or conflict of contractor(s),subcontractor (s),owner (s),project manager and all the stakeholders with contract.	8.1
42	Schedule compression techniques such as fast tracking and crashing may result in increased risk.	7.65
43	Poor or incorrect technical design due to incorrect or insufficient available information (geological ,geotechnical,..).	7.45
44	Project manager and functional manager(s) to resign.	7.25
45	Weld failure due to poor quality or lack of testing.	7.25
46	Collapse of slab due to early removal of the forms,props,etc.	7.2
47	Change in design due to change in design standards during design process.	7
48	Non standard or inappropriate contract form (type or form of the contract is not standard or compatible with laws).	6.95
49	Exchange rate fluctuation.	6.9
50	Delay in delivery of ready mixed concrete during pouring concrete.	6.7
51	Natural disasters such as earthquake,flood,landslide,fire,storm and glacial weather,etc.	6.55

52	Unavailability (lack)or high price of manpower due to economic conditions in country.	6.3
53	Landslides due to hard rains during excavation phase which may lead to collapse of neighbouring buildings.	6.3
54	Unavailability (lack)or high price of needed equipments due to economic conditions in project region or country.	6.2
55	Failure of support systems or platform during pouring concrete.	6.15
56	Unwanted changes in laws and standards.	6.1
57	Delay of bank in project fund allocation.	6
58	Back bending due to hand troweling and manual screeding during pouring concrete (Slab & Foundation).	6
59	Collapse of structure due to members failure from temprary loading (Unexpected heavy winds) during erection.	6
60		5.95
61	Delay in approving the contractor(s) work by consultant(s) or owner(s) of the project.	5.95
62	Scope creep.	5.85
63	Litigation conflict with neighbor of the project.	5.8
64	Poor communication in project between different stakeholders.	5.65
65	Excavation machinery falls from unprotected edges (Machinery crashes).	5.65
66	Falling objects from height.	5.65
67	Manpower's damage by reinforcement wire and rebar 's sharp edges .	5.6
68	Delay of contractor in final billing presentation due to poor performance of personnel.	5.4
69	Manpower's falling down from openings or void spaces&ducts and edge of the work area .	5.35
70	Unavailability of needed information,code and standards.	5.3
71	Manpower's falling from edges of formwork frames during their erection.	5.3
72	Ground collapse.	5.15
73	Being struck by objects such as steel members (fall of construction materials and tools)	5.1
74	Injuries from worker's stumble and falling on the exposed steel rebars (Protruding rebar ends).	5.05
75	Manpower's falling from the height during erection of steel structure.	4.85
76	Irregular or inadequacy of site inspection by consultant(s) during implementation phase.	4.75
77	Injury of worker's due to slip onto form ply sheet (Slips & Trips).	4.7
78	Manpower's falling into an excavation.	4.65
79	Skill deficiency of project manager(s),contactor(s),subcontractor(s),owner(s),consultant(s) ,etc in internal management.	4.6
80	Failure of lifting equipments.	4.45
81	Crane overturn due to overloading.	4.45
82	Unavailability or lack of needed experts , professional managers and experienced contractors in project region.	4.4

83	Any change in management strategies, principles or change of manager(s) of the project,owner(s) and general contractor(s).	4.4
84	Probability of fire due to welding operation(Welding spatter,grinding spark in flammable environment).	4.35
85	Collapse of excavation sides due to instability of excavation.	4.3
86	A person being trapped by the collapse of an excavation.	4.2
87	Design is not appropriate with the project objectives or requirement of the project.	4.05
88	Political conflict with other countries.	3.9
89	Safe working load exceeded during lifting equipments and materials such as lumber,plywood,forms ,etc (Heavy lifting).	3.85
90	Exposure to underground water during excavation.	3.6
91	The project organization chart has not sufficient detail to identify the key personnel and their roles and responsibilities.	3.5
92	Crane slings or chains may be released during erection steel structure erection (columns,beams,etc.)	3.45
93	Injury of third parties and workers during steel structure erection.	3.3
94	Collapse of fresh concrete container (bucket,barrow,etc.) during pouring operations.	3.25
95	Strike during implementation phase.	3.1
96	Interest rate fluctuation.	3.05
97	Back bending and high hand force with repetition and awkward posture while tying rebars.	2.85
98	Corrosion of steel rebars.	2.8
99	Injuries from cutting and bending rebar.	2.8
100	Contact of wet concrete with eyes and skin during pouring concrete.	2.8
101	Being struck by objects (equipment & materials) such as concrete buckets.chutes,etc.	2.8
102	Heavy lifting of rebar is a potential risk factor.	2.55
103	Injury from manually handling the form ply sheets.	2.5
104	Manpower's slip and fall into reinforcement mesh (Slips & Trips).	2.45
105	Risk of injury from inhalation of toxic gases generated during welding.	2.2

Table 4.5: Identified risks rankings, considering cost

No.	Risk Events	Risk Rating Cost
1	Unavailability (lack)or high price of materials due to economic conditions in project region or country.	18.7
2	Allocation of risks to the contractor (s),subcontractor (s),owner (s),consultant(s),desiner(s),etc is not mentioned or is not clear in the contract.	18.65
3	Inaccurate or incorrect estimation of time,cost and resources in accordance with WBS.	18.6
4	Any unwanted weather conditions such as very cold,very hot,windy,rainy weather and snowy weather .	18.25
5	Any problem related to poor monitoring and controlling the quality of tasks execution in project.	17.75
6	Financial difficulties of contractor(s) and owner(s) of the project (Problems to provide project funds on time) .	17.7
7	Adjacent structures collapse (Collapse of neighbouring buildings) due to inadequate retaining walls.	17.5
8	Incorrect or insufficient design data.	16.7
9	Inflation rate unpredictably increasing.	16.65
10	Incompatibility of architectural, structural and mechanical,etc plans (Not coordinated design).	16.45
11	Any problem due to poor inspection of work by contractor (Technical mistakes ,etc)during implementation phase.	16.35
12	Any change in political situation such as sanction,etc.	16.3
13	Delay in payment to contractor(s) during project implementation phase.	16.25
14	Delay in materials deliveries by suppliers (Supplier's incompetency to deliver materials on time).	16
15	Lack of consideration of contingency reserve and management reseve in estimating cost and time of the project to encounter with known-unknown and unknown-unknown risks.	15.75
16	Late design variations by owner(s) of the project or late changes requested by stakeholders .	15.55
17	Contact with underground cables (essential services)and cutting them during excavation phase.	15.45
18	Instability and collapse of structure due to inadequate temporary bracing during steelwork.	15.2
19	Inconsistency or mistake in contract documents.	15.15
20	Fabrication errors (angles,etc.) and incomplete fabrication (missing components).	14.9
21	The lack of a precise definition of the project and defects in the project documents such as project charter,project scope statement,etc.	14.1

22	Deflection of slab after pouring concrete due to inadequate and inappropriate props installations,etc.	14.1
23	Collapse of structure due to inappropriate and poor welding of joints (between column,beam and bracing) during erection.	13.25
24	Formwork collapse during and after pouring concrete due to inadequate support and low strength to stand the pressure or weight of fresh concrete and vibration pressure,etc.	12.7
25	Economic slowdown or economic crisis .	12.5
26	Any problems and conflict between different partners of the project.	12.1
27	Poor or incorrect estimation in market,technical & financial analysis.	10.75
28	Applied schedule by inexperienced project manager is not consistent with the desired cost ,scope and quality of the project (inconsistent cost ,time,scope and quality objectives) .	10.55
29	Concrete cracks (Types of concrete cracks such as shrinkage crack,Tension crack ,etc).	10.45
30	Poor preliminary assessment and evaluation of different possibilities of treatment measures for ground and groundwater.	10.15
31	Schedule compression techniques such as fast tracking and crashing may result in increased risk.	10.15
32	Being struck by objects such as steel members (fall of construction materials and tools)	9.95
33	Incompetency of contractor/subcontractor due to lack of experience,equipments ,enough qualified experts and labors.	9.9
34	Delay in contract issue by owner of the project.	9.4
35	Market fluctuations (Low market demand , change in market demand ,etc).	9.4
36	Delay of bank in project fund allocation.	8.9
37	Mistake of designer (s) in calculations ,analysis and evaluations.	8.85
38	Any problem or conflict of contractor(s),subcontractor (s),owner (s),project manager and all the stakeholders with contract.	8.5
39	Exchange rate fluctuation.	7.95
40	Manpower's falling from the height during erection of steel structure.	7.9
41	Falling objects from height.	7.8
42	Poor or incorrect technical design due to incorrect or insufficient available information (geological ,geotechnical,...).	7.5
43	Weld failure due to poor quality or lack of testing.	7.5
44	Lack of consistency between bill of quantities ,drawings and specifications.	7.4
45	Damage to persons, properties and materials due to poor health and safety management of the project.	7.4

46	Delay in decision making of the project by inexperienced owner(s).	7.4
47	Delay of government to issue the project permissions (Requirement for permits and their approval take longer than expected).	7.4
48	Collapse of structure due to members failure from temprary loading (Unexpected heavy winds) during erection.	7.25
49	Injuries from worker's stumble and falling on the exposed steel rebars (Protruding rebar ends).	7.2
50	Landslides due to hard rains during excavation phase which may lead to collapse of neighbouring buildings.	7.15
51	Failure of support systems or platform during pouring concrete.	7.05
52	Change in design due to change in design standards during design process.	7
53	Project manager and functional manager(s) to resign.	7
54	Collapse of slab due to early removal of the forms,props,etc.	6.95
55	Excavation machinery falls from unprotected edges (Machinery crashes).	6.85
56	Non standard or inappropriate contract form (type or form of the contract is not standard or compatible with laws).	6.8
57	Manpower's falling down from openings or void spaces&ducts and edge of the work area .	6.6
58	Delay in delivery of ready mixed concrete during pouring concrete.	6.55
59	Delay in approving the contractor(s) work by consultant(s) or owner(s) of the project.	6.45
60	Unavailability (lack)or high price of manpower due to economic conditions in country.	6.4
61	Manpower's falling from edges of formwork frames during their erection.	6.4
62	Injury of third parties and workers during steel structure erection.	6.2
63	Manpower's damage by reinforcement wire and rebar 's sharp edges .	6.1
64	Project Funding difficulties due to bad financial situation of financier (s).	6
65	Safe working load exceeded during lifting equipments and materials such as lumber,plywood,forms ,etc (Heavy lifting).	6
66	Natural disasters such as earthquake,flood,landslide,fire,storm and glacial weather,etc.	6
67		5.9
68	Scope creep.	5.85
69	Delay in presenting design results or design drawing.	5.65
70	Delay of contractor in final billing presentation due to poor performance of personnel.	5.55
71	Poor communication in project between different stakeholders.	5.45
72	Unwanted changes in laws and standards.	5.45
73	Back bending due to hand troweling and manual screeding during pouring concrete (Slab & Foundation).	5.35

74	Unavailability (lack)or high price of needed equipments due to economic conditions in project region or country.	5.2
75	Being struck by objects (equipment & materials) such as concrete buckets.chutes,etc.	5.2
76	Unavailability of needed information,code and standards.	4.95
77	Ground collapse.	4.95
78	A person being trapped by the collapse of an excavation.	4.95
79	Unavailability or lack of needed experts , professional managers and experienced contractors in project region.	4.85
80	Skill deficiency of project manager(s),contactor(s),subcontractor(s),owner(s),consultant(s) ,etc in internal management.	4.8
81	Collapse of excavation sides due to instability of excavation.	4.8
82	Manpower's falling into an excavation.	4.75
83	Failure of lifting equipments.	4.6
84	Any change in management strategies, principles or change of manager(s) of the project,owner(s) and general contractor(s).	4.5
85	Probability of fire due to welding operation(Welding spatter,grinding spark in flammable environment).	4.5
86	Crane overturn due to overloading.	4.5
87	Design is not appropriate with the project objectives or requirement of the project.	4.45
88	Irregular or inadequacy of site inspection by consultant(s) during implementation phase.	4.45
89	Interest rate fluctuation.	4.2
90	Injury of worker's due to slip onto form ply sheet (Slips & Trips).	4.15
91	Exposure to underground water during excavation.	4.1
92	Collapse of fresh concrete container (bucket,barrow,etc.) during pouring operations.	3.9
93	Crane slings or chains may be released during erection steel structure erection (columns,beams,etc.)	3.7
94	Back bending and high hand force with repetition and awkward posture while tying rebars.	3.6
95	The project organization chart has not sufficient detail to identify the key personnel and their roles and responsibilities.	3.45
96	Strike during implementation phase.	3.2
97	Injury from manually handling the form ply sheets.	3.2
98	Political conflict with other countries.	3.1
99	Manpower's slip and fall into reinforcement mesh (Slips & Trips).	3.05
100	Corrosion of steel rebars.	3
101	Contact of wet concrete with eyes and skin during pouring concrete.	3
102	Litigation conflict with neighbor of the project.	2.95
103	Risk of injury from inhalation of toxic gases generated during welding.	2.9
104	Injuries from cutting and bending rebar.	2.8
105	Heavy lifting of rebar is a potential risk factor.	2.5

Table 4.6: Identified risks rankings, considering quality

No.	Risk Events	Risk Rating Quality
1	Any change in political situation such as sanction,etc.	18.65
2	Inaccurate or incorrect estimation of time,cost and resources in accordance with WBS.	18.2
3	Incompatibility of architectural, structural and mechanical,etc plans (Not coordinated design).	17.3
4	Deflection of slab after pouring concrete due to inadequate and inappropriate props installations,etc.	17.15
5	Financial difficulties of contractor(s) and owner(s) of the project (Problems to provide project funds on time) .	16.95
6	Any problem related to poor monitoring and controlling the quality of tasks execution in project.	16.85
7	Any problem due to poor inspection of work by contractor (Technical mistakes ,etc)during implementation phase.	16.55
8	Incorrect or insufficient design data.	16.5
9	Fabrication errors (angles,etc.) and incomplete fabrication (missing components).	15.55
10	Unavailability (lack)or high price of materials due to economic conditions in project region or country.	15.4
11	Formwork collapse during and after pouring concrete due to inadequate support and low strength to stand the pressure or weight of fresh concrete and vibration pressure,etc.	15.2
12	Any unwanted weather conditions such as very cold,very hot,windy,rainy weather and snowy weather .	14.3
13	Delay in payment to contractor(s) during project implementation phase.	14.25
14	Allocation of risks to the contractor (s),subcontractor (s),owner (s),consultant(s),desiner(s),etc is not mentioned or is not clear in the contract.	13.75
15	Collapse of structure due to inappropriate and poor welding of joints (between column,beam and bracing) during erection.	13.7
16	Inflation rate unpredictably increasing.	13.7

17	The lack of a precise definition of the project and defects in the project documents such as project charter,project scope statement,etc.	13.15
18	Late design variations by owner(s) of the project or late changes requested by stakeholders .	12.8
19	Lack of consideration of contingency reserve and management reseve in estimating cost and time of the project to encounter with known-unknown and unknown-unknown risks.	12.75
20	Any problems and conflict between different partners of the project.	12.45
21	Adjacent structures collapse (Collapse of neighbouring buildings) due to inadequate retaining walls.	12.15
22	Inconsistency or mistake in contract documents.	11.65
23	Concrete cracks (Types of concrete cracks such as shrinkage crack,Tension crack ,etc).	11.25
24	Instability and collapse of structure due to inadequate temporary bracing during steelwork.	10.25
25	Delay in materials deliveries by suppliers (Supplier's incompetency to deliver materials on time).	9.5
26	Mistake of designer (s) in calculations ,analysis and evaluations.	9.05
27	Applied schedule by inexperienced project manager is not consistent with the desired cost ,scope and quality of the project (inconsistent cost ,time,scope and quality objectives) .	8
28	Contact with underground cables (essential services)and cutting them during excavation phase.	7.9
29	Any problem or conflict of contractor(s),subcontractor (s),owner (s),project manager and all the stakeholders with contract.	7.8
30	Lack of consistency between bill of quantities ,drawings and specifications.	7.75
31	Incompetency of contractor/subcontractor due to lack of experience,equipments ,enough qualified experts and labors.	7.7
32	Delay in delivery of ready mixed concrete during pouring concrete.	7.7
33	Poor or incorrect technical design due to incorrect or insufficient available information (geological ,geotechnical,..).	7.35
34	Schedule compression techniques such as fast tracking and crashing may result in increased risk.	7.35
35	Failure of support systems or platform during pouring concrete.	7.35

36	Weld failure due to poor quality or lack of testing.	7.1
37		7.05
38	Exchange rate fluctuation.	6.95
39	Economic slowdown or economic crisis .	6.8
40	Poor or incorrect estimation in market,technical & financial analysis.	6.7
41	Project manager and functional manager(s) to resign.	6.55
42	Market fluctuations (Low market demand , change in market demand ,etc).	6.5
43	Natural disasters such as earthquake,flood,landslide,fire,storm and glacial weather,etc.	6.35
44	Poor communication in project between different stakeholders.	6.1
45	Damage to persons, properties and materials due to poor health and safety management of the project.	6.05
46	Unwanted changes in laws and standards.	5.8
47	Unavailability (lack)or high price of needed equipments due to economic conditions in project region or country.	5.55
48	Collapse of slab due to early removal of the forms,props,etc.	5.5
49	Project Funding difficulties due to bad financial situation of financier (s).	5.45
50	Unavailability (lack)or high price of manpower due to economic conditions in country.	5.45
51	Unavailability of needed information,code and standards.	5.4
52	Poor preliminary assessment and evaluation of different possibilities of treatment measures for ground and groundwater.	5.3
53	Non standard or inappropriate contract form (type or form of the contract is not standard or compatible with laws).	5.25
54	Change in design due to change in design standards during design process.	5.25
55	Being struck by objects such as steel members (fall of construction materials and tools)	5.2
56	Scope creep.	5.05
57	Delay of bank in project fund allocation.	5
58	Skill deficiency of project manager(s),contactor(s),subcontractor(s),owner(s),consultant(s) ,etc in internal management.	5
59	Corrosion of steel rebars.	5

60	Delay of contractor in final billing presentation due to poor performance of personnel.	4.95
61	Landslides due to hard rains during excavation phase which may lead to collapse of neighbouring buildings.	4.65
62	Delay in decision making of the project by inexperienced owner(s).	4.6
63	Injuries from worker's stumble and falling on the exposed steel rebars (Protruding rebar ends).	4.3
64	Design is not appropriate with the project objectives or requirement of the project.	4.25
65	Excavation machinery falls from unprotected edges (Machinery crashes).	4.25
66	Unavailability or lack of needed experts , professional managers and experienced contractors in project region.	4.15
67	Back bending due to hand troweling and manual screeding during pouring concrete (Slab & Foundation).	4.15
68	Falling objects from height.	4.05
69	Irregular or inadequacy of site inspection by consultant(s) during implementation phase.	3.95
70	Political conflict with other countries.	3.9
71	Any change in management strategies, principles or change of manager(s) of the project,owner(s) and general contractor(s).	3.85
72	Delay in contract issue by owner of the project.	3.75
73	Manpower's damage by reinforcement wire and rebar 's sharp edges .	3.6
74	Delay in presenting design results or design drawing.	3.55
75	Injury of worker's due to slip onto form ply sheet (Slips & Trips).	3.55
76	Delay in approving the contractor(s) work by consultant(s) or owner(s) of the project.	3.45
77	Ground collapse.	3.45
78	Collapse of fresh concrete container (bucket,barrow,etc.) during pouring operations.	3.4
79	Delay of government to issue the project permissions (Requirement for permits and their approval take longer than expected).	3.35
80	Contact of wet concrete with eyes and skin during pouring concrete.	3.3
81	Strike during implementation phase.	3.1
82	Interest rate fluctuation.	3.1
83	Failure of lifting equipments.	3.05

84	Crane slings or chains may be released during erection steel structure erection (columns,beams,etc.)	3.05
85	Collapse of excavation sides due to instability of excavation.	3
86	Probability of fire due to welding operation(Welding spatter,grinding spark in flammable environment).	3
87	Collapse of structure due to members failure from temprary loading (Unexpected heavy winds) during erection.	3
88	Litigation conflict with neighbor of the project.	2.7
89	Safe working load exceeded during lifting equipments and materials such as lumber,plywood,forms ,etc (Heavy lifting).	2.7
90	Crane overturn due to overloading.	2.65
91	Exposure to underground water during excavation.	2.6
92	Injuries from cutting and bending rebar.	2.55
93	Manpower's falling down from openings or void spaces&ducts and edge of the work area .	2.55
94	Injury from manually handling the form ply sheets.	2.5
95	Manpower's falling from edges of formwork frames during their erection.	2.45
96	Injury of third parties and workers during steel structure erection.	2.35
97	Back bending and high hand force with repetition and awkward posture while tying rebars.	2.3
98	Risk of injury from inhalation of toxic gases generated during welding.	2.3
99	Manpower's slip and fall into reinforcement mesh (Slips & Trips).	2.2
100	Being struck by objects (equipment & materials) such as concrete buckets.chutes,etc.	2.15
101	The project organization chart has not sufficient detail to identify the key personnel and their roles and responsibilities.	2.05
102	Heavy lifting of rebar is a potential risk factor.	1.95
103	Manpower's falling from the height during erection of steel structure.	1.85
104	A person being trapped by the collapse of an excavation.	1.8
105	Manpower's falling into an excavation.	1.75

Table 4.7: Identified risks rankings, considering health and safety

No.	Risk Events	Risk Rating Health& Safety
1	Adjacent structures collapse (Collapse of neighbouring buildings) due to inadequate retaining walls.	18
2	Instability and collapse of structure due to inadequate temporary bracing during steelwork.	16.1
3	Collapse of structure due to inappropriate and poor welding of joints (between column,beam and bracing) during erection.	13.45
4	Damage to persons, properties and materials due to poor health and safety management of the project.	11.05
5	Financial difficulties of contractor(s) and owner(s) of the project (Problems to provide project funds on time) .	11
6	Injuries from worker's stumble and falling on the exposed steel rebars (Protruding rebar ends).	10.65
7	Any unwanted weather conditions such as very cold,very hot,windy,rainy weather and snowy weather .	10.1
8	Any problem related to poor monitoring and controlling the quality of tasks execution in project.	8.9
9	Falling objects from height.	8.65
10	Any change in political situation such as sanction,etc.	8.6
11	Any problem due to poor inspection of work by contractor (Technical mistakes ,etc)during implementation phase.	8.5
12	Being struck by objects such as steel members (fall of construction materials and tools)	8.4
13	Manpower's falling from the height during erection of steel structure.	8.25
14	Incompetency of contractor/subcontractor due to lack of experience,equipments ,enough qualified experts and labors.	8.1
15	Deflection of slab after pouring concrete due to inadequate and inappropriate props installations,etc.	8.05
16	Formwork collapse during and after pouring concrete due to inadequate support and low strength to stand the pressure or weight of fresh concrete and vibration pressure,etc.	8
17	Inflation rate unpredictably increasing.	7.95
18	Manpower's falling from edges of formwork frames during their erection.	7.6
19	Collapse of structure due to members failure from temprary loading (Unexpected heavy winds) during erection.	7.6
20	Collapse of slab due to early removal of the forms,props,etc.	7.35
21	Contact with underground cables (essential services)and cutting them during excavation phase.	7.2
22	Natural disasters such as earthquake,flood,landslide,fire,storm and glacial weather,etc.	6.9
23	Manpower's falling down from openings or void spaces&ducts and edge of the work area .	6.8

24	Failure of support systems or platform during pouring concrete.	6.7
25	Landslides due to hard rains during excavation phase which may lead to collapse of neighbouring buildings.	6.6
26	Unavailability of needed information,code and standards.	6.55
27	Fabrication errors (angles,etc.) and incomplete fabrication (missing components).	6.45
28	Injury of worker's due to slip onto form ply sheet (Slips & Trips).	6.35
29	Safe working load exceeded during lifting equipments and materials such as lumber,plywood,forms ,etc (Heavy lifting).	6.3
30	Concrete cracks (Types of concrete cracks such as shrinkage crack,Tension crack ,etc).	6.3
31	Excavation machinery falls from unprotected edges (Machinery crashes).	6.25
32	Failure of lifting equipments.	6.05
33	Ground collapse.	6
34	Collapse of fresh concrete container (bucket,barrow,etc.) during pouring operations.	5.9
35	Injury of third parties and workers during steel structure erection.	5.85
36	Manpower's damage by reinforcement wire and rebar 's sharp edges .	5.75
37	Inaccurate or incorrect estimation of time,cost and resources in accordance with WBS.	5.7
38	Back bending due to hand troweling and manual screeding during pouring concrete (Slab & Foundation).	5.45
39	Schedule compression techniques such as fast tracking and crashing may result in increased risk.	5.35
40	Lack of consideration of contingency reserve and management reseve in estimating cost and time of the project to encounter with known-unknown and unknown-unknown risks.	5.3
41	Manpower's falling into an excavation.	5.2
42	Delay in payment to contractor(s) during project implementation phase.	5.15
43	A person being trapped by the collapse of an excavation.	5.15
44	Any problems and conflict between different partners of the project.	5.1
45	Being struck by objects (equipment & materials) such as concrete buckets.chutes,etc.	5.1
46	Probability of fire due to welding operation(Welding spatter,grinding spark in flammable environment).	5.1
47	Exchange rate fluctuation.	5.1
48	Applied schedule by inexperienced project manager is not consistent with the desired cost ,scope and quality of the project (inconsistent cost ,time,scope and quality objectives) .	5.05
49	Delay in materials deliveries by suppliers (Supplier's incompetency to deliver materials on time).	5.05

50	Crane slings or chains may be released during erection steel structure erection (columns,beams,etc.)	5
51	Economic slowdown or economic crisis .	4.9
52		4.85
53	Market fluctuations (Low market demand , change in market demand ,etc).	4.85
54	Allocation of risks to the contractor (s),subcontractor (s),owner (s),consultant(s),desiner(s),etc is not mentioned or is not clear in the contract.	4.8
55	Incompatibility of architectural, structural and mechanical,etc plans (Not coordinated design).	4.8
56	Skill deficiency of project manager(s),contactor(s),subcontractor(s),owner(s),consultant(s) ,etc in internal management.	4.7
57	Poor or incorrect technical design due to incorrect or insufficient available information (geological ,geotechnical,..).	4.6
58	Late design variations by owner(s) of the project or late changes requested by stakeholders .	4.6
59	Crane overturn due to overloading.	4.55
60	Collapse of excavation sides due to instability of excavation.	4.5
61	Inconsistency or mistake in contract documents.	4.45
62	The lack of a precise definition of the project and defects in the project documents such as project charter,project scope statement,etc.	4.3
63	Delay in delivery of ready mixed concrete during pouring concrete.	4.3
64	Unavailability (lack)or high price of materials due to economic conditions in project region or country.	4.25
65	Back bending and high hand force with repetition and awkward posture while tying rebars.	4.25
66	Any problem or conflict of contractor(s),subcontractor (s),owner (s),project manager and all the stakeholders with contract.	4.15
67	Heavy lifting of rebar is a potential risk factor.	4.15
68	Incorrect or insufficient design data.	4.1
69	Manpower's slip and fall into reinforcement mesh (Slips & Trips).	4.1
70	Delay of bank in project fund allocation.	4.05
71	Weld failure due to poor quality or lack of testing.	4
72	Injury from manually handling the form ply sheets.	3.95
73	Contact of wet concrete with eyes and skin during pouring concrete.	3.95
74	Poor preliminary assessment and evaluation of different possibilities of treatment measures for ground and groundwater.	3.9
75	Irregular or inadequacy of site inspection by consultant(s) during implementation phase.	3.6
76	Project manager and functional manager(s) to resign.	3.6

77	Any change in management strategies, principles or change of manager(s) of the project,owner(s) and general contractor(s).	3.55
78	Strike during implementation phase.	3.5
79	Mistake of designer (s) in calculations ,analysis and evaluations.	3.4
80	Unwanted changes in laws and standards.	3.4
81	Non standard or inappropriate contract form (type or form of the contract is not standard or compatible with laws).	3.35
82	Project Funding difficulties due to bad financial situation of financier (s).	3.3
83	Poor or incorrect estimation in market,technical & financial analysis.	3.25
84	Delay in contract issue by owner of the project.	3.2
85	Litigation conflict with neighbor of the project.	3.15
86	Injuries from cutting and bending rebar.	3.15
87	Lack of consistency between bill of quantities ,drawings and specifications.	3.1
88	Scope creep.	2.95
89	Delay in decision making of the project by inexperienced owner(s).	2.95
90	Risk of injury from inhalation of toxic gases generated during welding.	2.95
91	Unavailability or lack of needed experts , professional managers and experienced contractors in project region.	2.9
92	Change in design due to change in design standards during design process.	2.85
93	Delay in presenting design results or design drawing.	2.75
94	Delay of contractor in final billing presentation due to poor performance of personnel.	2.7
95	Delay of government to issue the project permissions (Requirement for permits and their approval take longer than expected	2.7
96	Poor communication in project between different stakeholders.	2.55
97	The project organization chart has not sufficient detail to identify the key personnel and their roles and responsibilities.	2.45
98	Delay in approving the contractor(s) work by consultant(s) or owner(s) of the project.	2.4
99	Unavailability (lack)or high price of manpower due to economic conditions in country.	2.35
100	Unavailability (lack)or high price of needed equipments due to economic conditions in project region or country.	2.3
101	Corrosion of steel rebars.	2.3
102	Interest rate fluctuation.	2.25
103	Political conflict with other countries.	2.25
104	Design is not appropriate with the project objectives or requirement of the project.	1.9
105	Exposure to underground water during excavation.	1.8

Table 4.8: Overall ranking of risks

NO.	Risk Event NO.	Risk Event	Overall Risk Rank	Rank Time	Rank Cost	Rank Quality	Rank Health and Safety
1	14	Inaccurate or incorrect estimation of time,cost and resources in accordance with WBS.	16.47419	1	3	2	
2	50	Adjacent structures collapse (Collapse of neighbouring buildings) due to inadequate retaining walls.	16.375005	4	7	21	1
3	45	Financial difficulties of contractor(s) and owner(s) of the project (Problems to provide project funds on time) .	16.23248	5	6	5	
4	95	Any unwanted weather conditions such as very cold,very hot,windy,rainy weather and snowy weather .	15.76589	2	4	12	
5	102	Any change in political situation such as sanction,etc.	15.455085	11	12	1	
6	28	Any problem related to poor monitoring and controlling the quality of tasks execution in project.	15.210345	16	5	6	
7	40	Any problem due to poor inspection of work by contractor (Technical mistakes ,etc)during implementation phase.	14.97988	9	11	7	
8	24	Unavailability (lack)or high price of materials due to economic conditions in project region or country.	14.77529	7	1	10	
9	15	Incompatibility of architectural, structural and mechanical,etc plans (Not coordinated design).	14.670015	6	10	3	
10	82	Instability and collapse of structure due to inadequate temporary bracing during steelwork.	14.442885	14	18		2
11	18	Incorrect or insufficient design data.	14.182275	12	8	8	
12	36	Delay in payment to contractor(s) during project implementation phase.	13.823435	8	13	13	
13	10	Allocation of risks to the contractor (s),subcontractor (s),owner (s),consultant(s),desiner(s),etc is not mentioned or is not clear in the contract.	13.70592	19	2	14	
14	46	Late design variations by owner(s) of the project or late changes requested by stakeholders .	13.524995	3	16	18	
15	70	Deflection of slab after pouring concrete due to inadequate and inappropriate props installations,etc.	13.51608	22	22	4	
16	83	Collapse of structure due to inappropriate and poor welding of joints (between column,beam and bracing) during erection.	13.491975	20	23	15	3
17	98	Inflation rate unpredictably increasing.	13.438305	21	9	16	
18	93	Fabrication errors (angles,etc.) and incomplete fabrication (missing components).	13.426515	18	20	9	
19	66	Formwork collapse during and after pouring concrete due to inadequate support and low strength to stand the pressure or weight of fresh concrete and vibration pressure,etc.	13.29783	15	24	11	
20	49	Delay in materials deliveries by suppliers (Supplier's incompetency to deliver materials on time).	12.53078	10	14		
21	57	Contact with underground cables (essential services)and cutting them during excavation phase.	12.31763	13	17		
22	33	Lack of consideration of contingency reserve and management reseve in estimating cost and time of the project to encounter with known-unknown and unknown-unknown risks.	12.28628	23	15	19	

23	12	The lack of a precise definition of the project and defects in the project documents such as project charter,project scope statement,etc.	12.278225	17	21	17	
24	8	Inconsistency or mistake in contract documents.	11.4077	26	19		
25	44	Any problems and conflict between different partners of the project.	10.853145	25	26	20	
26	99	Economic slowdown or economic crisis .	9.53247	27	25		
27	77	Concrete cracks (Types of concrete cracks such as shrinkage crack,Tension crack ,etc).	9.358625				
28	43	Incompetency of contractor/subcontractor due to lack of experience,equipments ,enough qualified experts and labors.	8.998725				
29	30	Applied schedule by inexperienced project manager is not consistent with the desired cost ,scope and quality of the project (inconsistent cost ,time,scope and quality objectives) .	8.793005				
30	5	Poor or incorrect estimation in market,technical & financial analysis.	8.491015				
31	31	Damage to persons, properties and materials due to poor health and safety management of the project.	8.02521				4
32	20	Mistake of designer (s) in calculations ,analysis and evaluations.	7.912395				
33	32	Schedule compression techniques such as fast tracking and crashing may result in increased risk.	7.883275		27		
34	7	Delay in contract issue by owner of the project.	7.752265	24			
35	97	Market fluctuations (Low market demand , change in market demand ,etc).	7.708055				
36	9	Any problem or conflict of contractor(s),subcontractor (s),owner (s),project manager and all the stakeholders with contract.	7.41115				
37	6	Poor preliminary assessment and evaluation of different possibilities of treatment measures for ground and groundwater.	7.40927				
38	85	Being struck by objects such as steel members (fall of construction materials and tools)	7.157955				
39	13	Lack of consistency between bill of quantities ,drawings and specifications.	7.108235				
40	16	Poor or incorrect technical design due to incorrect or insufficient available information (geological ,geotechnical,..).	6.91059				
41	101	Exchange rate fluctuation.	6.88452				
42	76	Failure of support systems or platform during pouring concrete.	6.800845				
43	72	Collapse of slab due to early removal of the forms,props,etc.	6.749445				
44	92	Weld failure due to poor quality or lack of testing.	6.683015				
45	47	Delay in decision making of the project by inexperienced owner(s).	6.571615				

46	59	Injuries from worker's stumble and falling on the exposed steel rebars (Protruding rebar ends).	6.541715					5
47	67	Falling objects from height.	6.45636					
48	75	Delay in delivery of ready mixed concrete during pouring concrete.	6.447345					
49	96	Natural disasters such as earthquake,flood,landslide,fire,storm and glacial weather,etc.	6.40559					
50	3	Project Funding difficulties due to bad financial situation of financier (s).	6.3719					
51	48	Project manager and functional manager(s) to resign.	6.3313					
52	4	Delay of bank in project fund allocation.	6.24918					
53	51	Landslides due to hard rains during excavation phase which may lead to collapse of neighbouring buildings.	6.21171					
54	105	Delay of government to issue the project permissions (Requirement for permits and their approval take longer than expected)	6.17117					
55	25		5.99206					
56	90	Collapse of structure due to members failure from temprary loading (Unexpected heavy winds) during erection.	5.949355					
57	11	Non standard or inappropriate contract form (type or form of the contract is not standard or compatible with laws).	5.83203					
58	19	Change in design due to change in design standards during design process.	5.811905					
59	55	Excavation machinery falls from unprotected edges (Machinery crashes).	5.779575					
60	89	Manpower's falling from the height during erection of steel structure.	5.66149					
61	1	Unavailability of needed information,code and standards.	5.452925					
62	23	Unavailability (lack)or high price of manpower due to economic conditions in country.	5.392555					
63	21	Delay in presenting design results or design drawing.	5.375395					
64	68	Manpower's falling from edges of formwork frames during their erection.	5.371205					
65	104	Unwanted changes in laws and standards.	5.335845					
66	79	Manpower's falling down from openings or void spaces&ducts and edge of the work area .	5.31913					
67	64	Manpower's damage by reinforcement wire and rebar 's sharp edges .	5.29806					
68	80	Back bending due to hand troweling and manual screeding during pouring concrete (Slab & Foundation).	5.26658					
69	27	Poor communication in project between different stakeholders.	5.12189					
70	35	Scope creep.	5.120275					
71	22	Unavailability (lack)or high price of needed equipments due to economic conditions in project region or country.	5.027025					
72	52	Ground collapse.	4.844365					
73	42	Delay in approving the contractor(s) work by consultant(s) or owner(s) of the project.	4.841615					
74	38	Delay of contractor in final billing presentation due to poor performance of personnel.	4.83471					
75	41	Skill deficiency of project manager(s),contactor(s),subcontractor(s),owner(s),consultant(s) ,etc in internal management.	4.7719					

76	69	Safe working load exceeded during lifting equipments and materials such as lumber,plywood,forms ,etc (Heavy lifting).	4.661405				
77	73	Injury of worker's due to slip onto form ply sheet (Slips & Trips).	4.57131				
78	84	Failure of lifting equipments.	4.45774				
79	87	Injury of third parties and workers during steel structure erection.	4.397445				
80	39	Irregular or inadequacy of site inspection by consultant(s) during implementation phase.	4.257605				
81	86	Probability of fire due to welding operation(Welding spatter,grinding spark in flammable environment).	4.211715				
82	26	Unavailability or lack of needed experts , professional managers and experienced contractors in project region.	4.19328				
83	53	Collapse of excavation sides due to instability of excavation.	4.17401				
84	29	Any change in management strategies, principles or change of manager(s) of the project,owner(s) and general contractor(s).	4.140095				
85	56	Manpower's falling into an excavation.	4.091125				
86	88	Crane overturn due to overloading.	4.05457				
87	54	A person being trapped by the collapse of an excavation.	4.024955				
88	74	Collapse of fresh concrete container (bucket,barrow,etc.) during pouring operations.	3.968245				
89	17	Design is not appropriate with the project objectives or requirement of the project.	3.814945				
90	81	Being struck by objects (equipment & materials) such as concrete buckets.chutes,etc.	3.775865				
91	2	Litigation conflict with neighbor of the project.	3.734225				
92	91	Crane slings or chains may be released during erection steel structure erection (columns,beams,etc.)	3.71576				
93	103	Political conflict with other countries.	3.35856				
94	61	Corrosion of steel rebars.	3.28882				
95	100	Interest rate fluctuation.	3.250015				
96	37	Strike during implementation phase.	3.20332				
97	65	Back bending and high hand force with repetition and awkward posture while tying rebars.	3.198815				
98	78	Contact of wet concrete with eyes and skin during pouring concrete.	3.19096				
99	58	Exposure to underground water during excavation.	3.17385				
100	71	Injury from manually handling the form ply sheets.	2.97433				
101	34	The project organization chart has not sufficient detail to identify the key personnel and their roles and responsibilities.	2.94495				
102	63	Manpower's slip and fall into reinforcement mesh (Slips & Trips).	2.87271				
103	62	Injuries from cutting and bending rebar.	2.805275				
104	60	Heavy lifting of rebar is a potential risk factor.	2.68963				
105	94	Risk of injury from inhalation of toxic gases generated during welding.	2.56809				

4.3.3 Risk Response

Risk response is the other step of risk management process, which is successive to risk identification and analysis. It is obvious from its title that in this stage, decisions and proper actions are developed to be taken when meeting the risks, focusing on the most critical ones, and are meant to minimize the negative effects of the threats. Various options were counted before as the list of risk response actions, namely, mitigation, transference, acceptance and avoidance (PMI, 2013).

Figures 4.21, 4.22, 4.23 and 4.24 indicate the data analyses and high impact risks on the projects' objective, which must be further considered in the risk response stage. From the least to highest, there are 5 critical risks in health and safety category, 21 critical risks in quality, and 27 ones in both cost and time category of the projects' objectives, which are separately being shown in Tables 4.4, 4.5, 4.6 and 4.6, marked with dark gray color. The other less critical risks are also being shown in the tables, with less intensity tones of gray (light for moderate risks, and medium for the least critical risks.).

4.4 Application of Probability and Impact Matrix (PIM) Technique

The participants in this survey were asked to respond and assess the probability and the impact of risks and assign numbers to them.

To demonstrate the techniques and steps of a risk management process, which is the core objective, the matrix tables of the five high ranked risks of each of the project objectives are shown in Figures 4.1 to 4.20. Meanwhile, in appendices G and H, samples of matrix table and survey participants' scores are shown.

In the following, the matrix tables of the five high ranked risks considering time, evaluated by each respondent based on probability and impact amounts are shown in Figures 4.1 to 4.5.

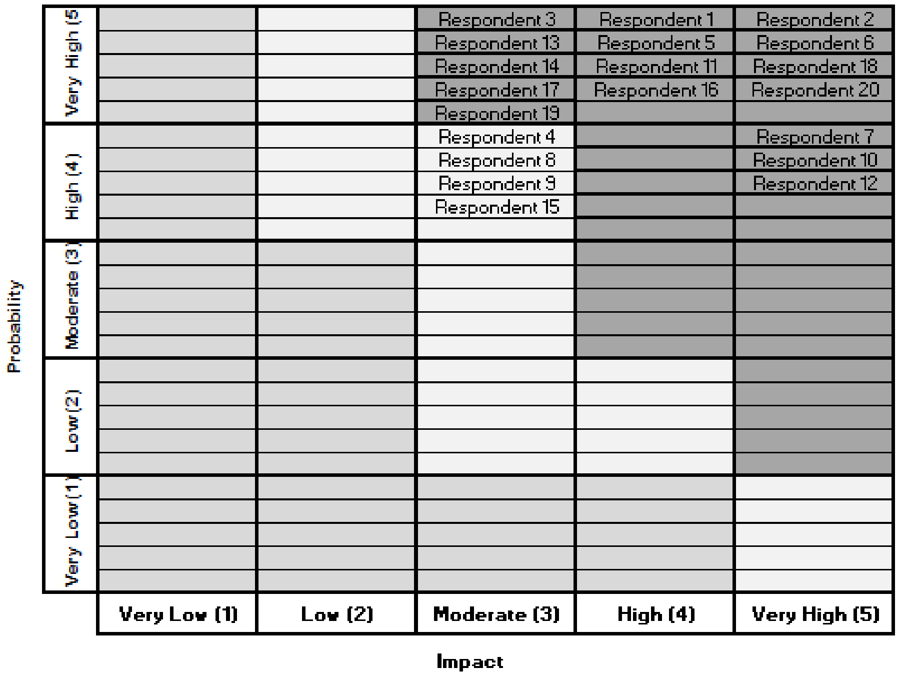

Figure 4.1: Matrix table of “Inaccurate or incorrect estimation of time, cost and resources in accordance with WBS” by all respondents

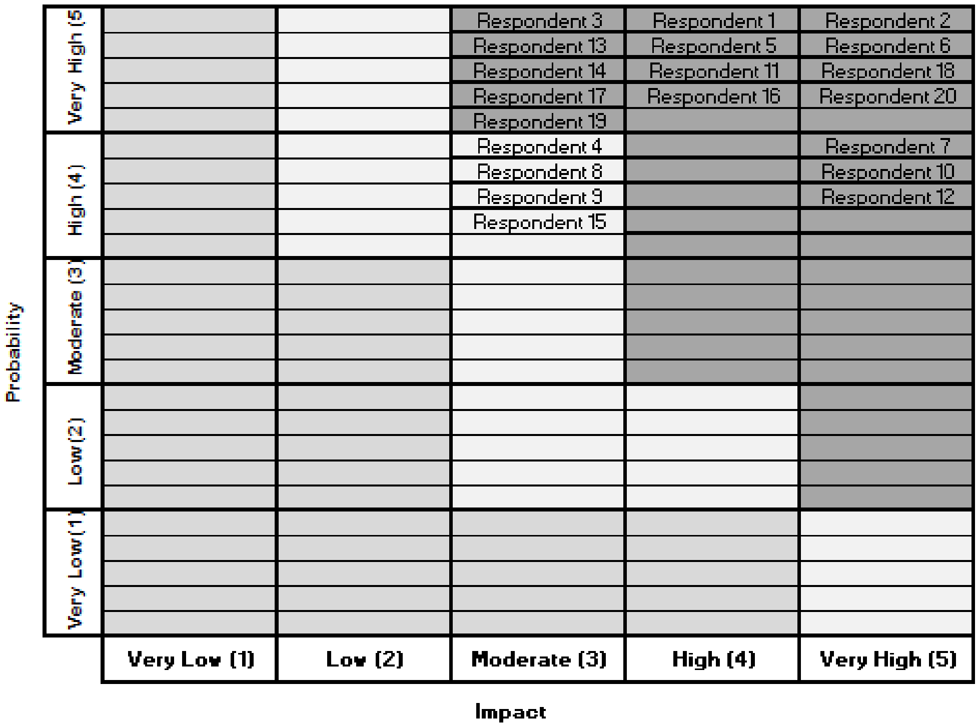

Figure 4.2: Matrix table of “Any unwanted weather conditions such as very cold, very hot, windy, rainy weather and snowy weather “by all respondents

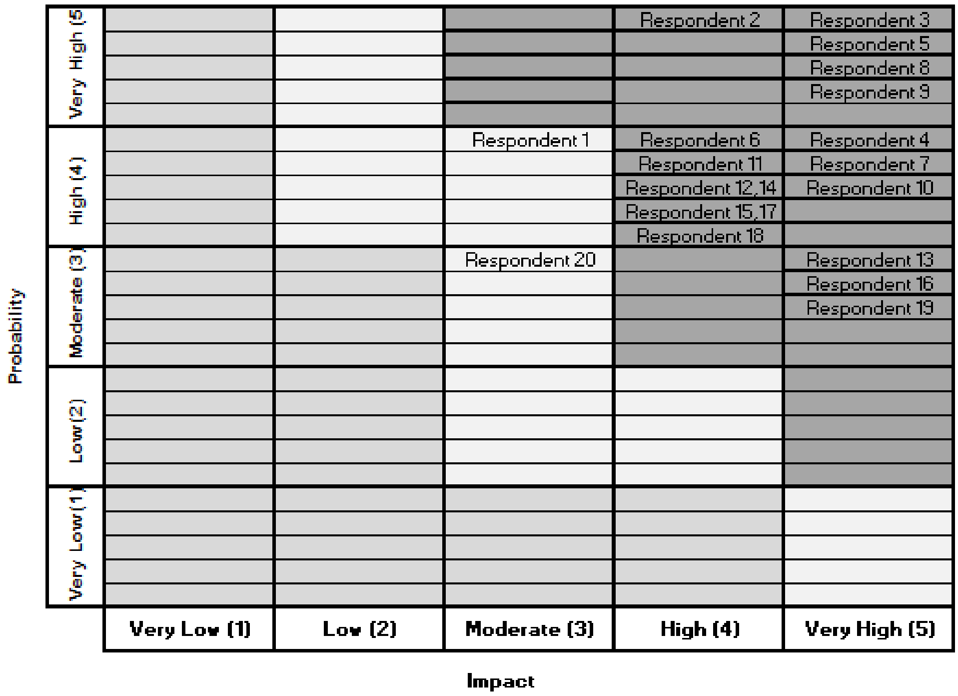

Figure 4.3: Matrix table of "Late design variations by owner(s) of the project or late changes requested by stakeholders" by all respondents

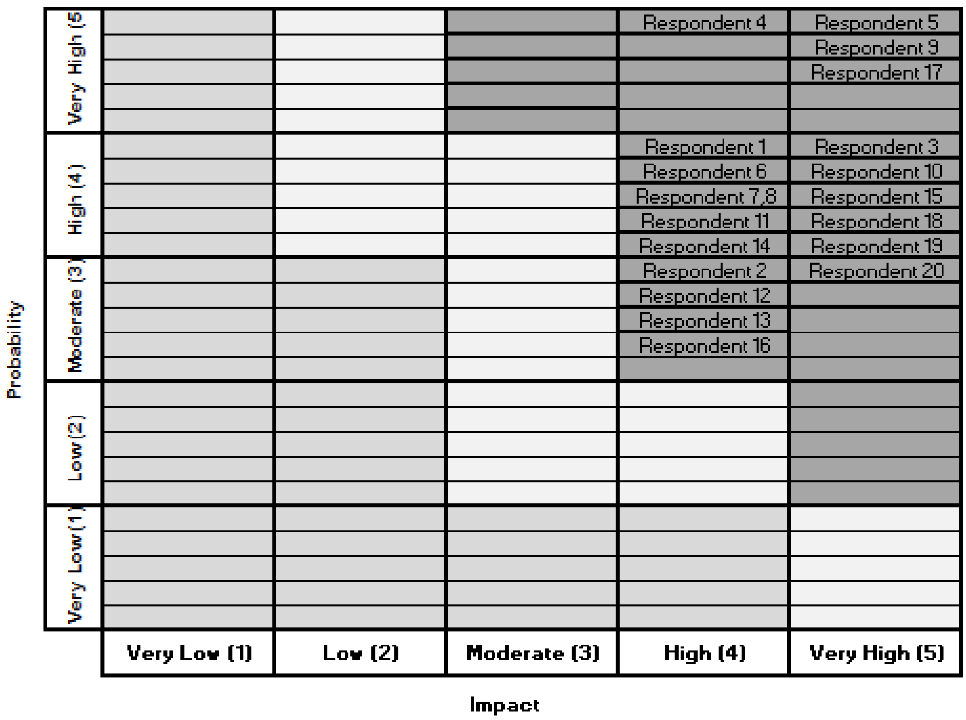

Figure 4.4: Matrix table of "Adjacent structures collapse (Collapse of neighboring buildings) due to inadequate retaining walls "by all respondents

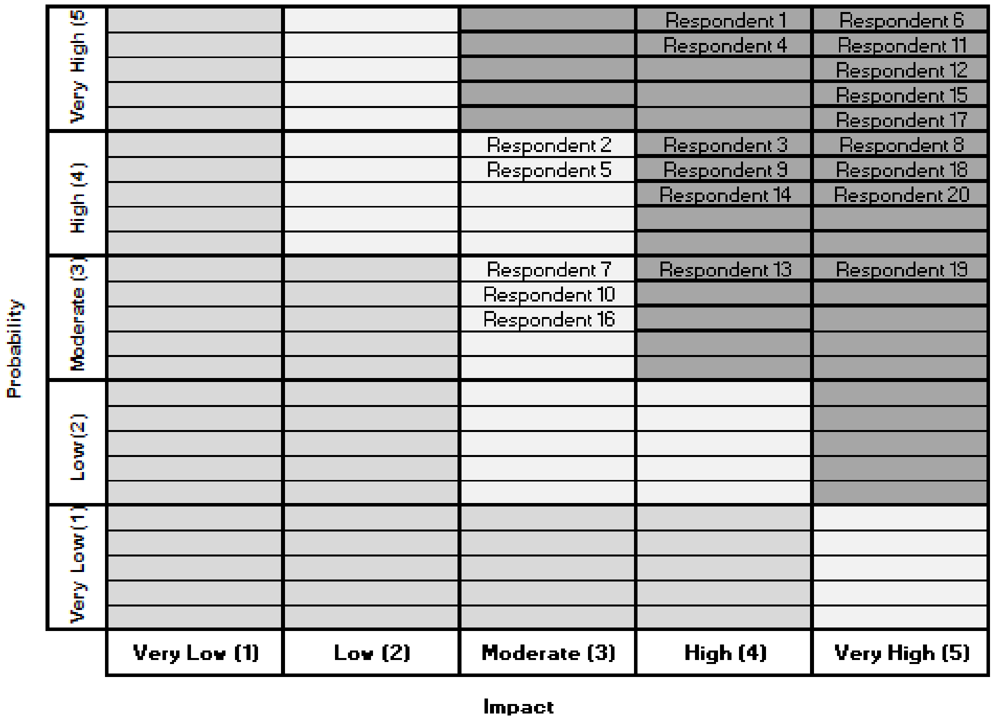

Figure 4.5: Matrix table of "Financial difficulties of contractor(s) and owner(s) of the project (Problems to provide project funds on time)" by all respondents

Similarly, the matrix tables of the five high ranked risks considering cost, evaluated by each respondent based on probability and impact amounts are shown in Figures 4.6 to 4.10.

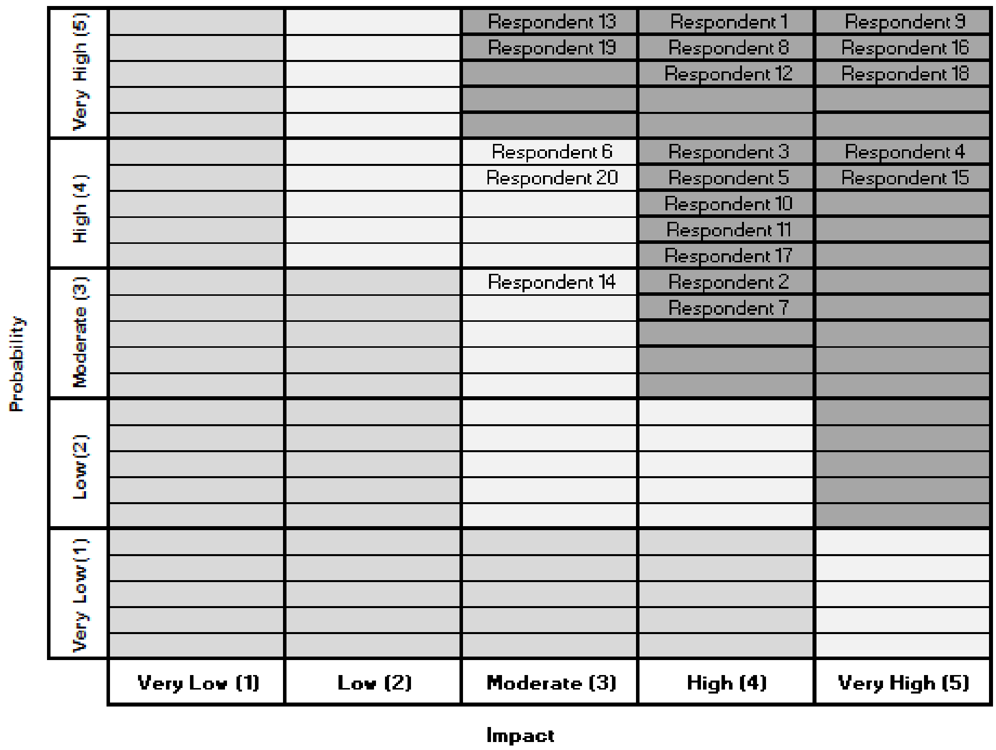

Figure 4.6: Matrix table of "Unavailability (lack) or high price of materials due to economic conditions in project region or country" by all respondents

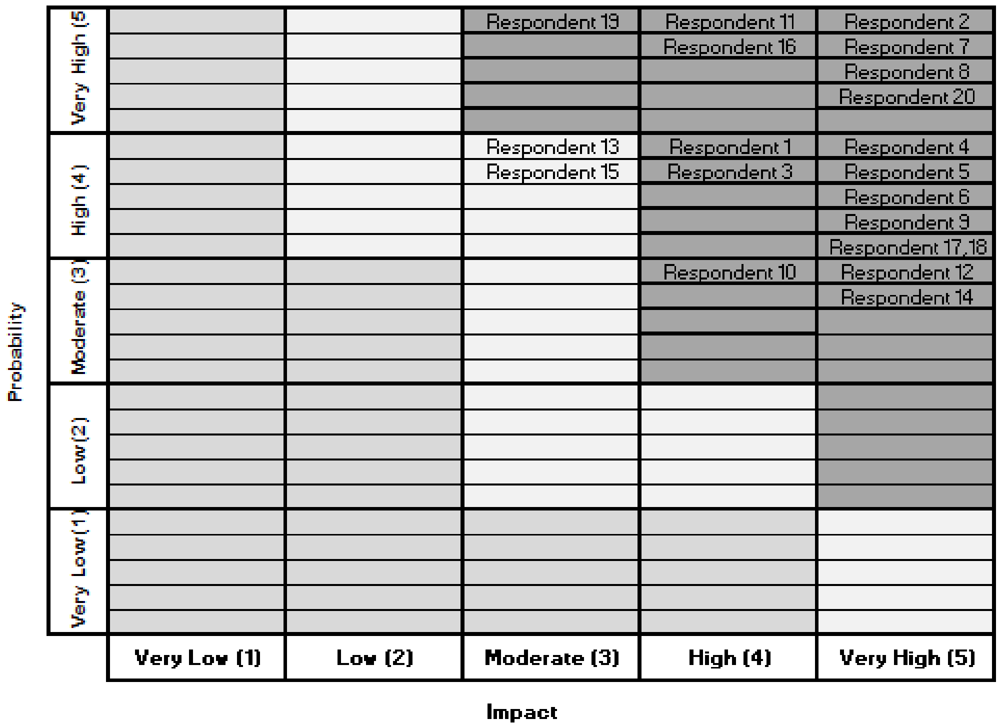

Figure 4.7: Matrix table of "Allocation of risks to the contractor (s), subcontractor (s), owner (s), consultant(s),designer(s), etc. is not mentioned or is not clear in the contract" by all respondents

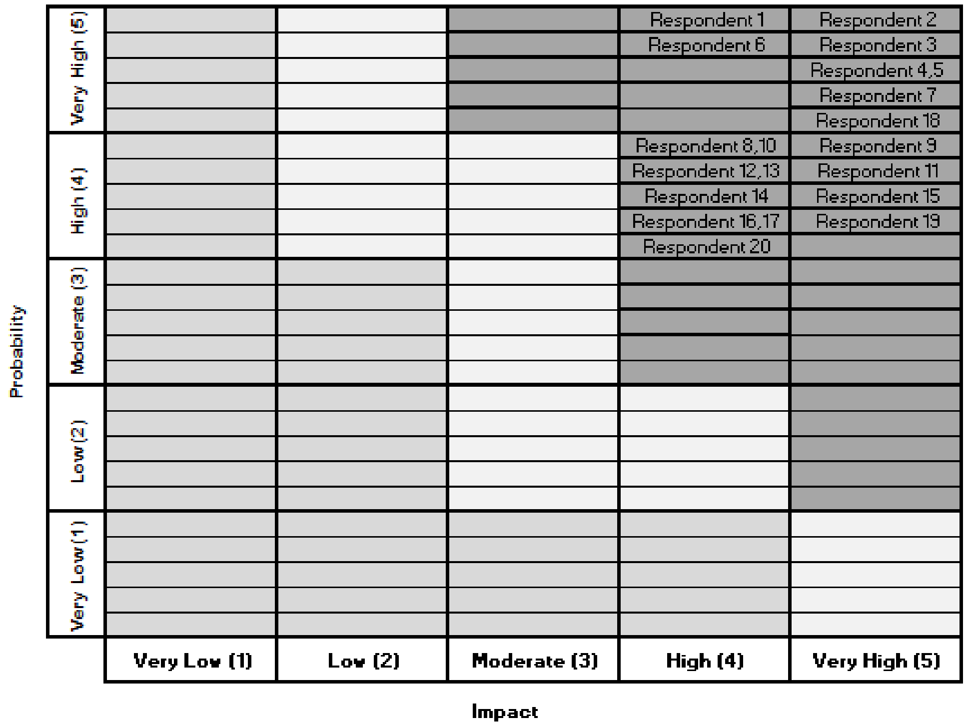

Figure 4.8: Matrix table of "Inaccurate or incorrect estimation of time, cost and resources in accordance with WBS" by all respondents

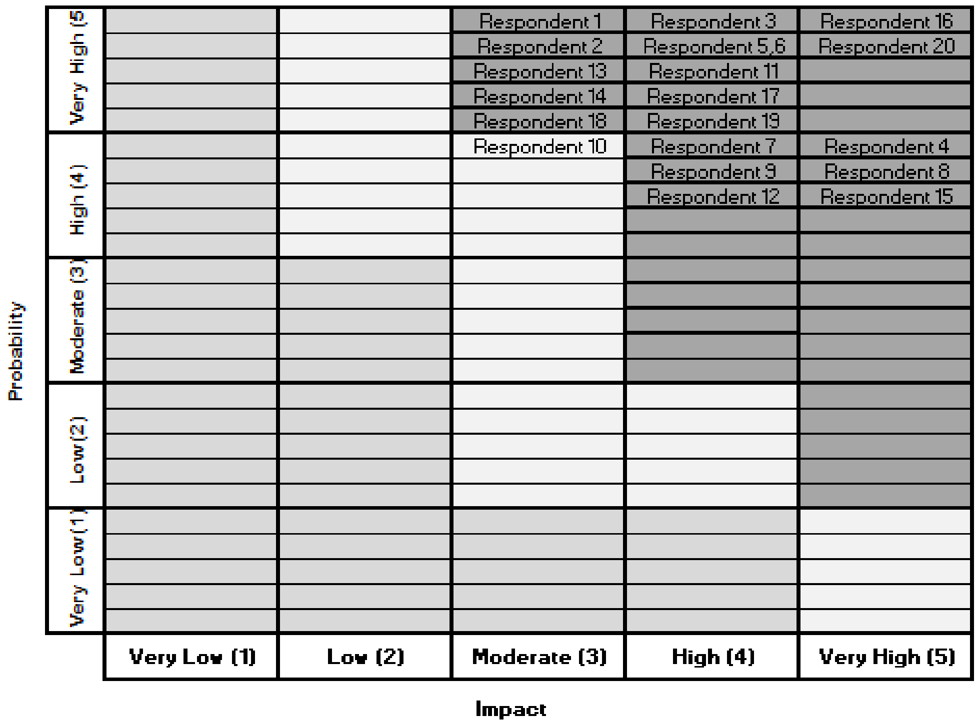

Figure 4.9: Matrix table of "Any unwanted weather conditions such as very cold, very hot, windy, rainy weather and snowy weather" by all respondents

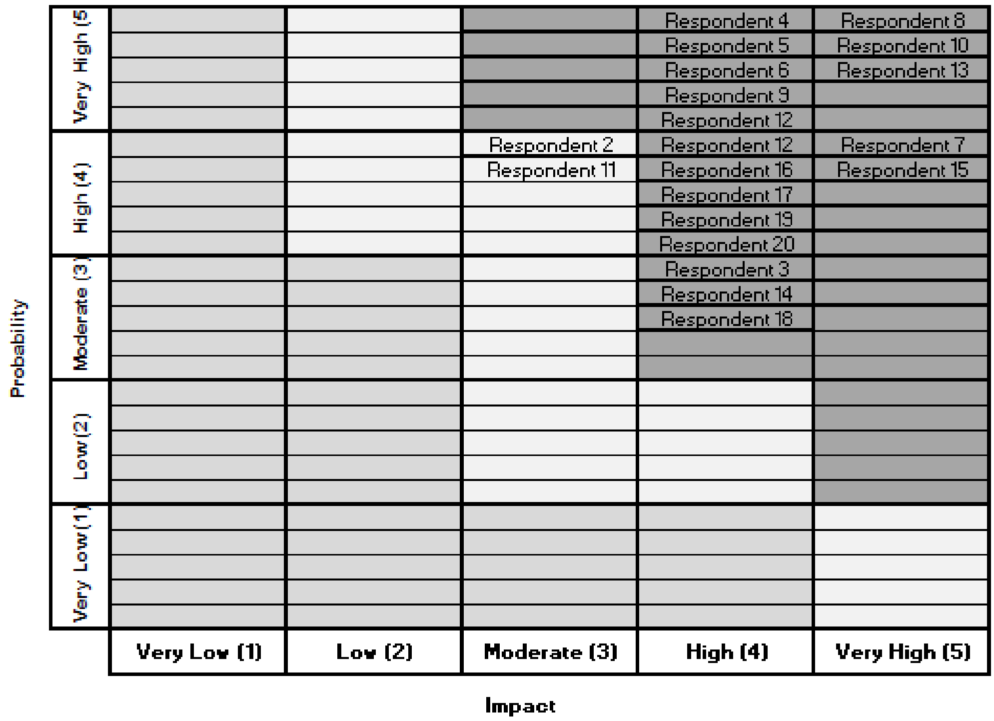

Figure 4.10: Matrix table of "Any problem related to poor monitoring and controlling the quality of tasks execution in project" by all respondents

In addition, the matrix tables of the five high ranked risks considering quality, evaluated by each respondent based on probability and impact amounts are presented in Figures 4.11 to 4.15.

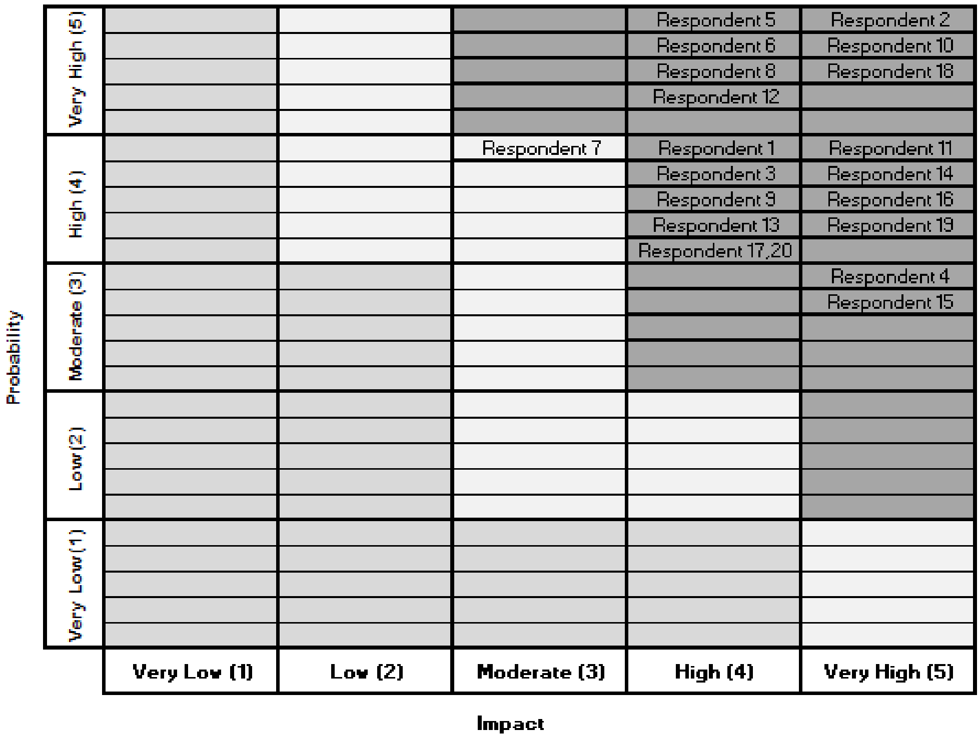

Figure 4.11: Matrix table of "Any change in political situation such as sanction, etc." By all respondents

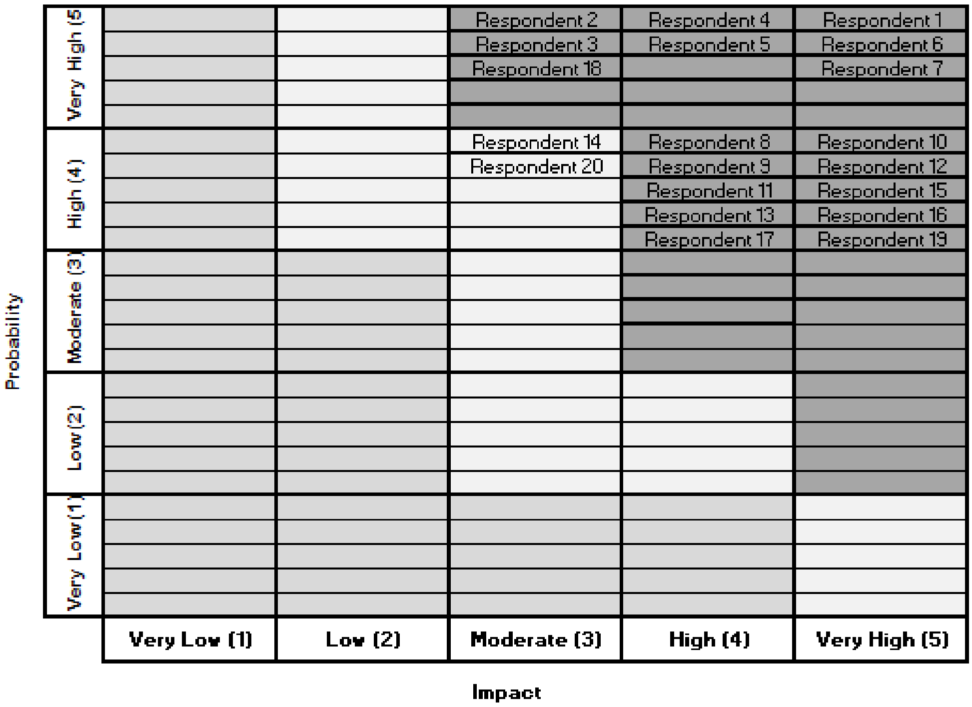

Figure 4.12: Matrix table of "Inaccurate or incorrect estimation of time, cost and resources in accordance with WBS" by all respondents

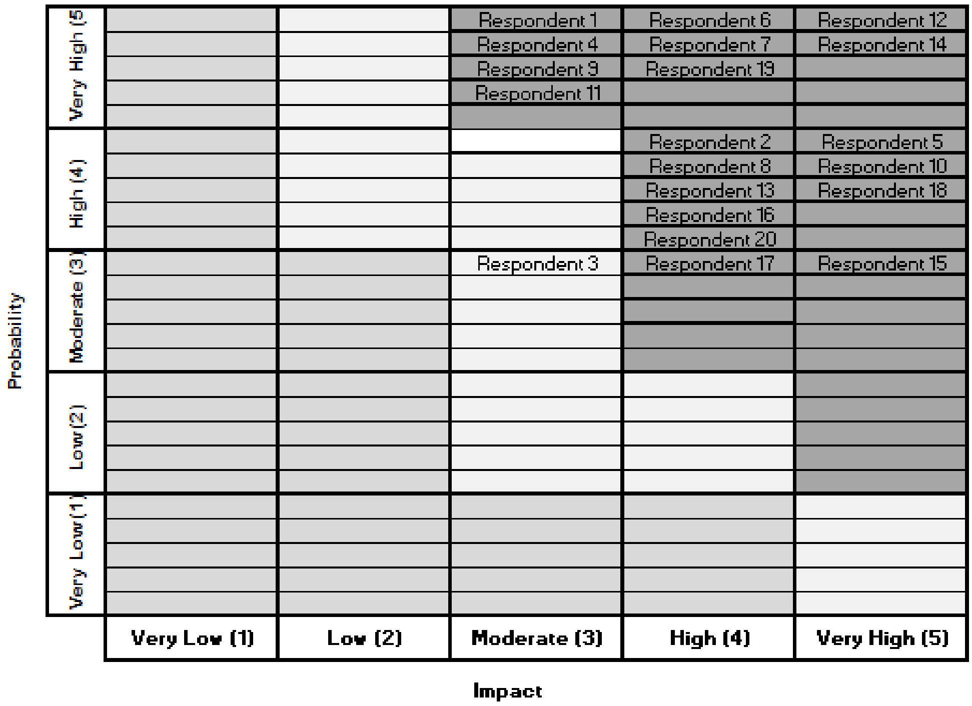

Figure 4.13: Matrix table of “Incompatibility of architectural, structural and mechanical, etc. plans (Not coordinated design)”by all respondents

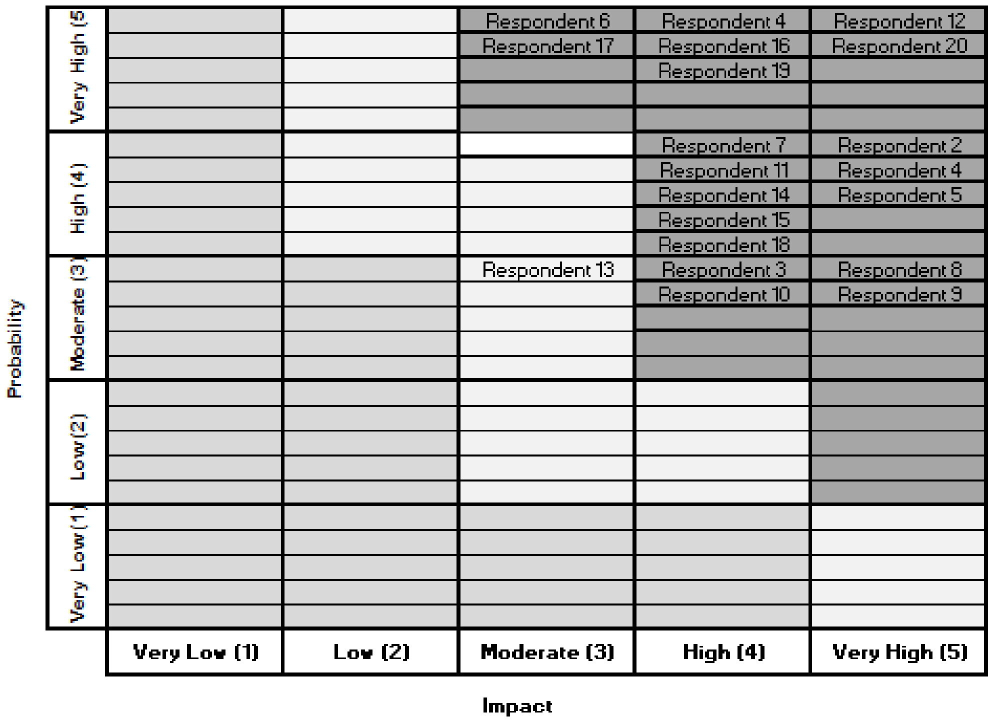

Figure 4.14: Matrix table of “Deflection of slab after pouring concrete due to inadequate and inappropriate props installations, etc. “by all respondents

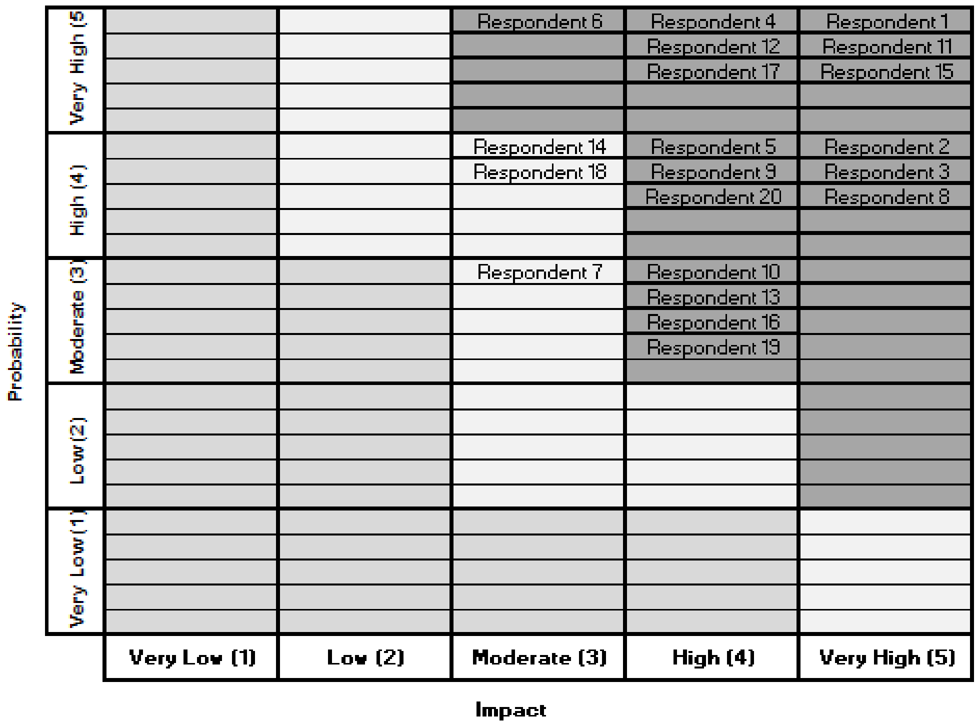

Figure 4.15: Matrix table of “Financial difficulties of contractor(s) and owner(s) of the project (Problems to provide project funds on time)”by all respondents

Eventually, the matrix tables of the five high ranked risks considering health and safety, evaluated by each respondent based on probability and impact amounts are also illustrated in Figures 4.16 to 4.20.

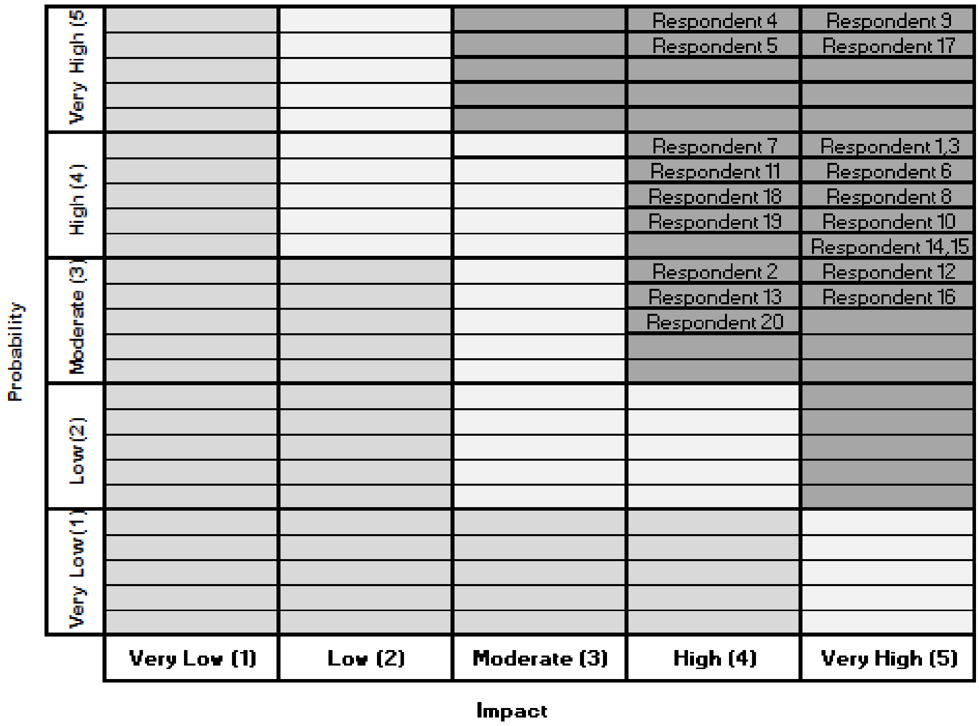

Figure 4.16: Matrix table of "Adjacent structures collapse (Collapse of neighboring buildings) due to inadequate retaining walls" by all respondents

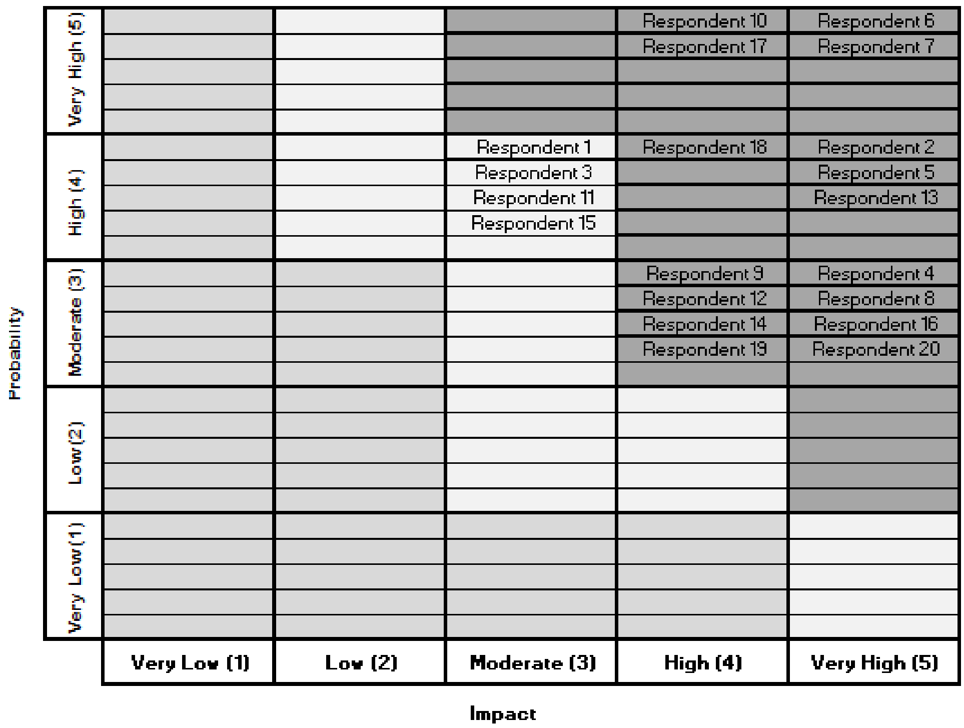

Figure 4.17: Matrix table of "Instability and collapse of structure due to inadequate temporary bracing during steelwork" by all respondents

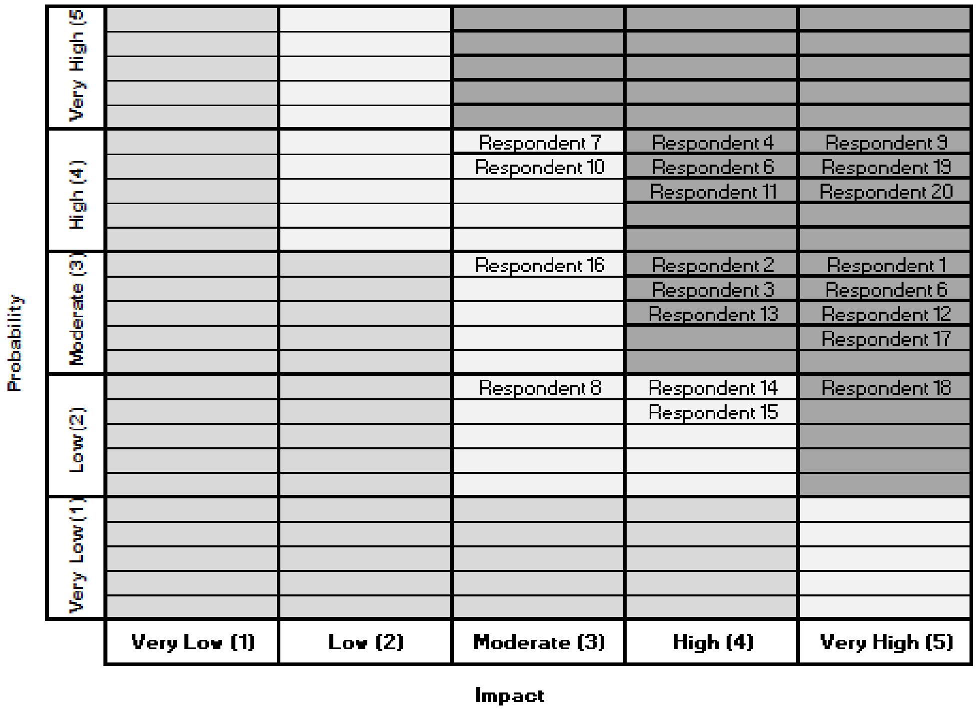

Figure 4.18: Matrix table of "Collapse of structure due to inappropriate and poor welding of joints (between column, beam and bracing) during erection" by all respondents

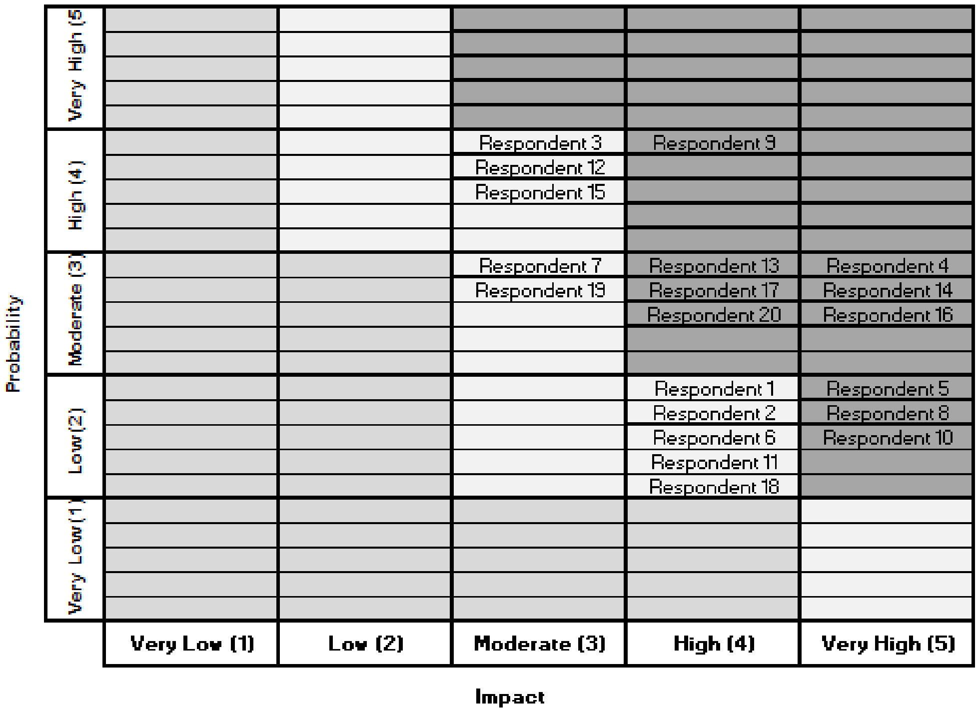

Figure 4.19: Matrix table of "Damage to persons, properties and materials due to poor health and safety management of the project "by all respondents

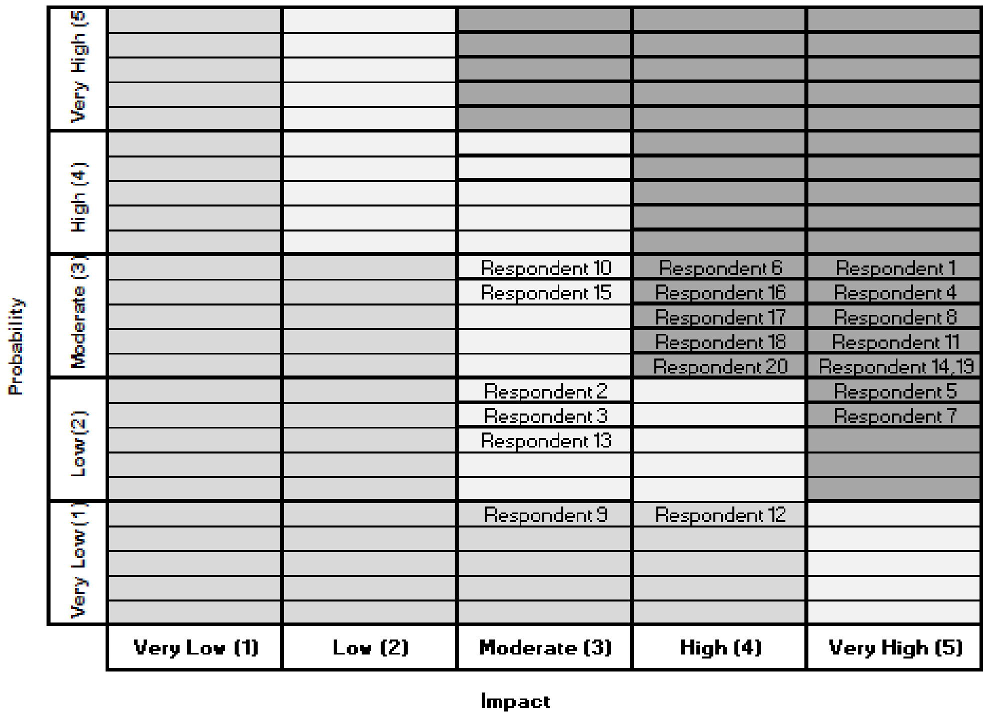

Figure 4.20: Matrix table of “Injuries from worker's stumble and falling on the exposed steel rebars (Protruding rebar ends)”by all respondents

Figures 4.21, 4.22, 4.23, 4.24 and 4.25 indicate the high impact risks on the projects’ objectives (time, cost. quality and health and safety), and ranking the risks overall which must be further considered in the risk response stage.

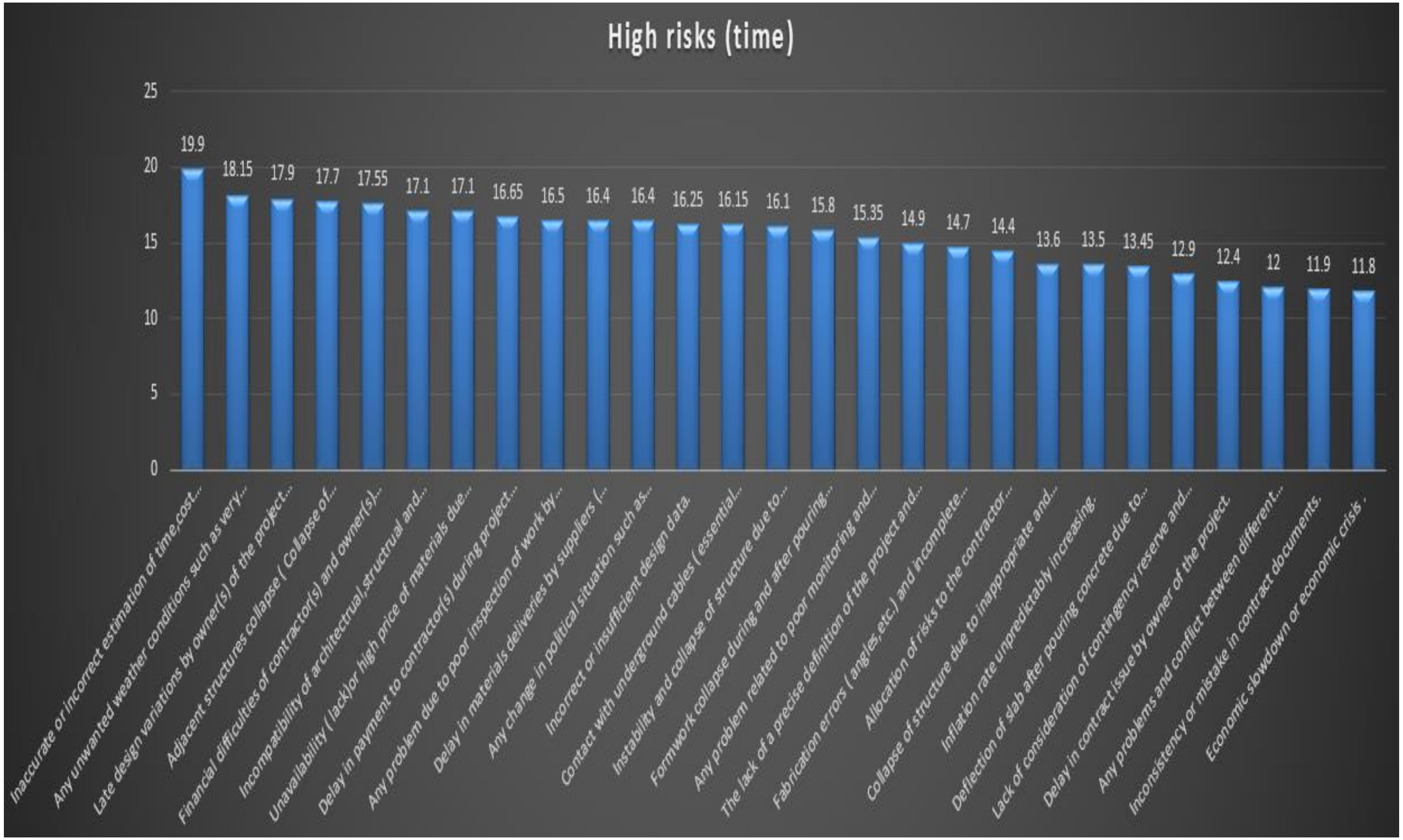

Figure 4.21: Critical risks of time

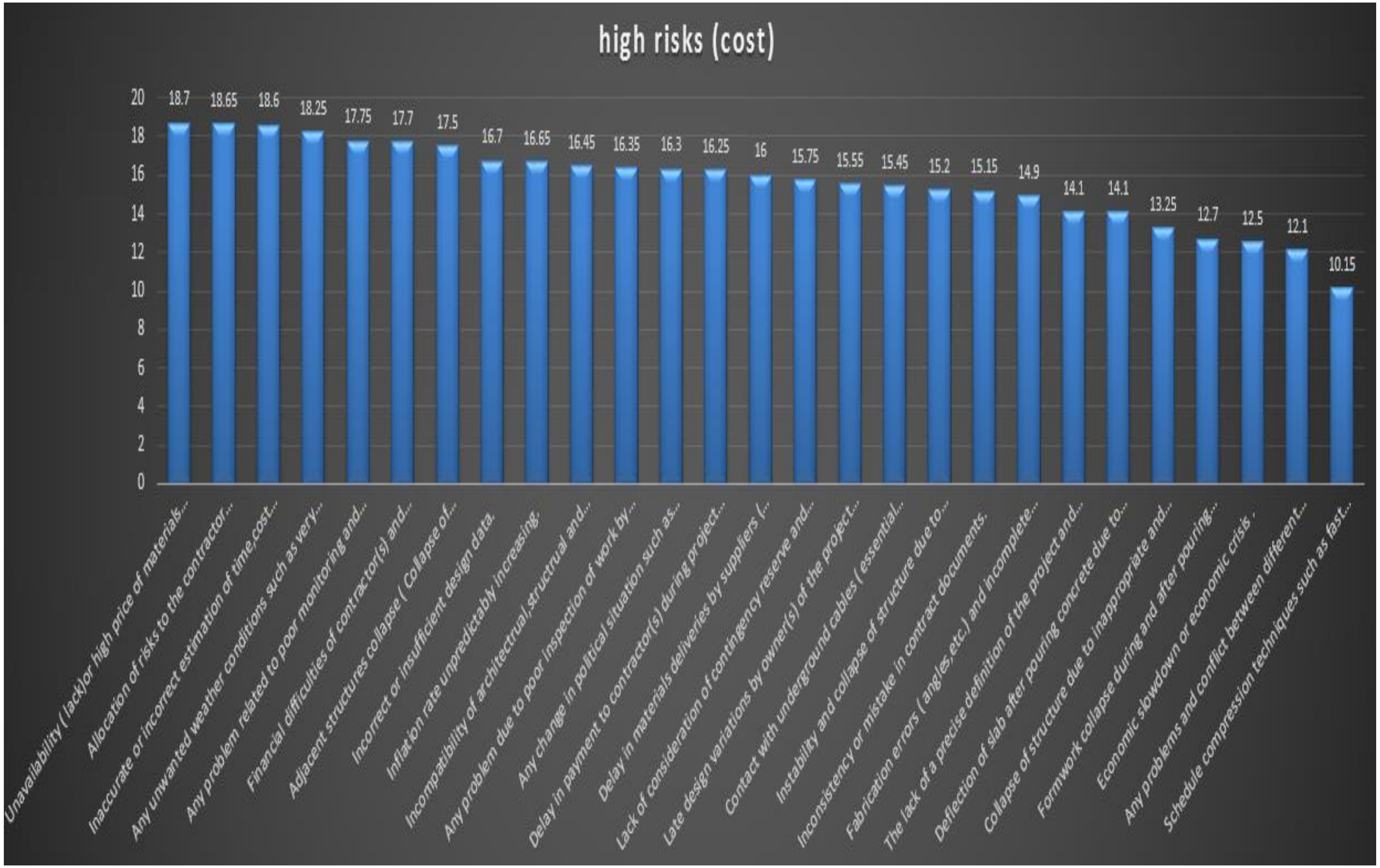

Figure 4.22: Critical risks of cost

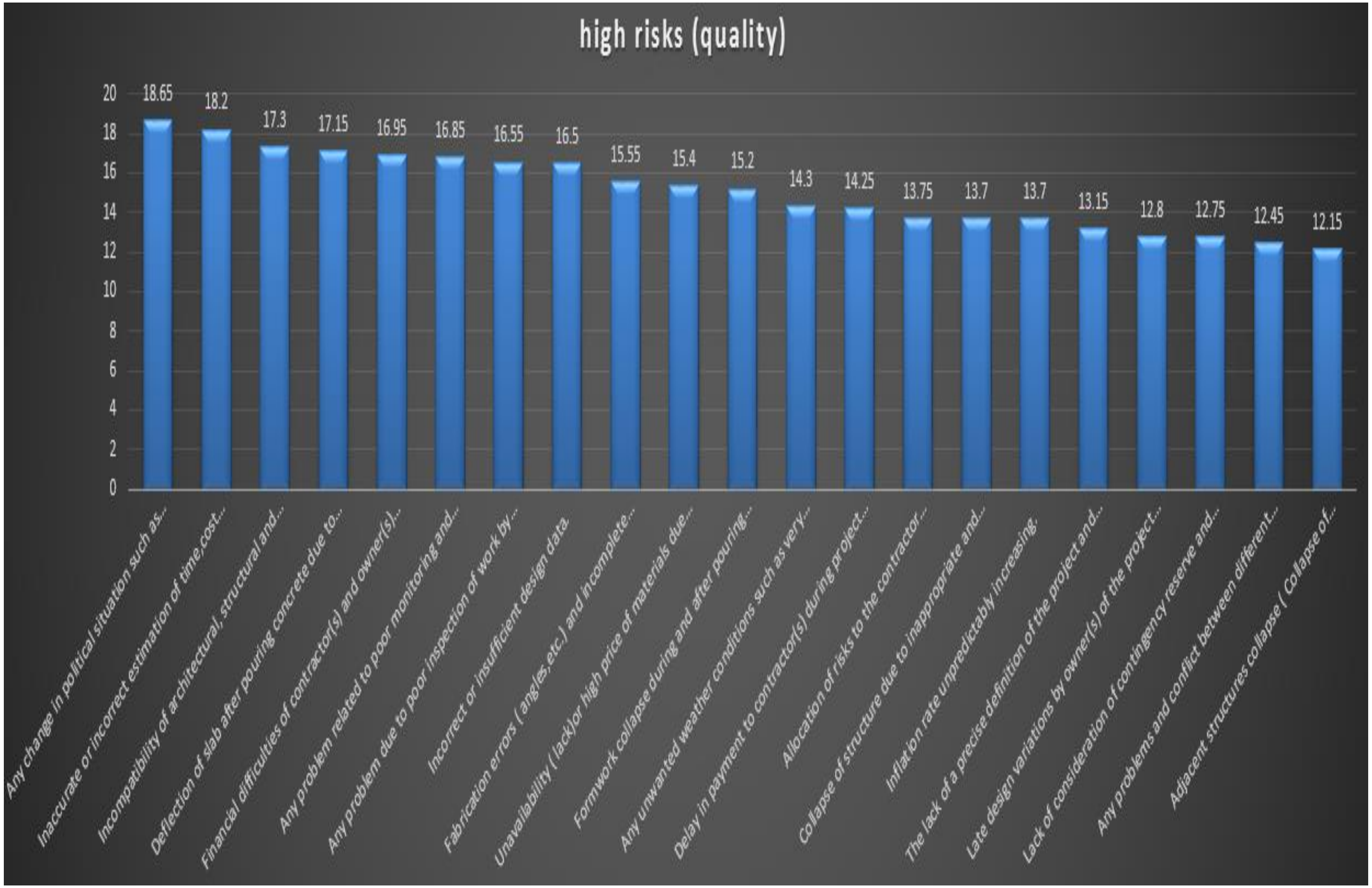

Figure 4.23: Critical risks of quality

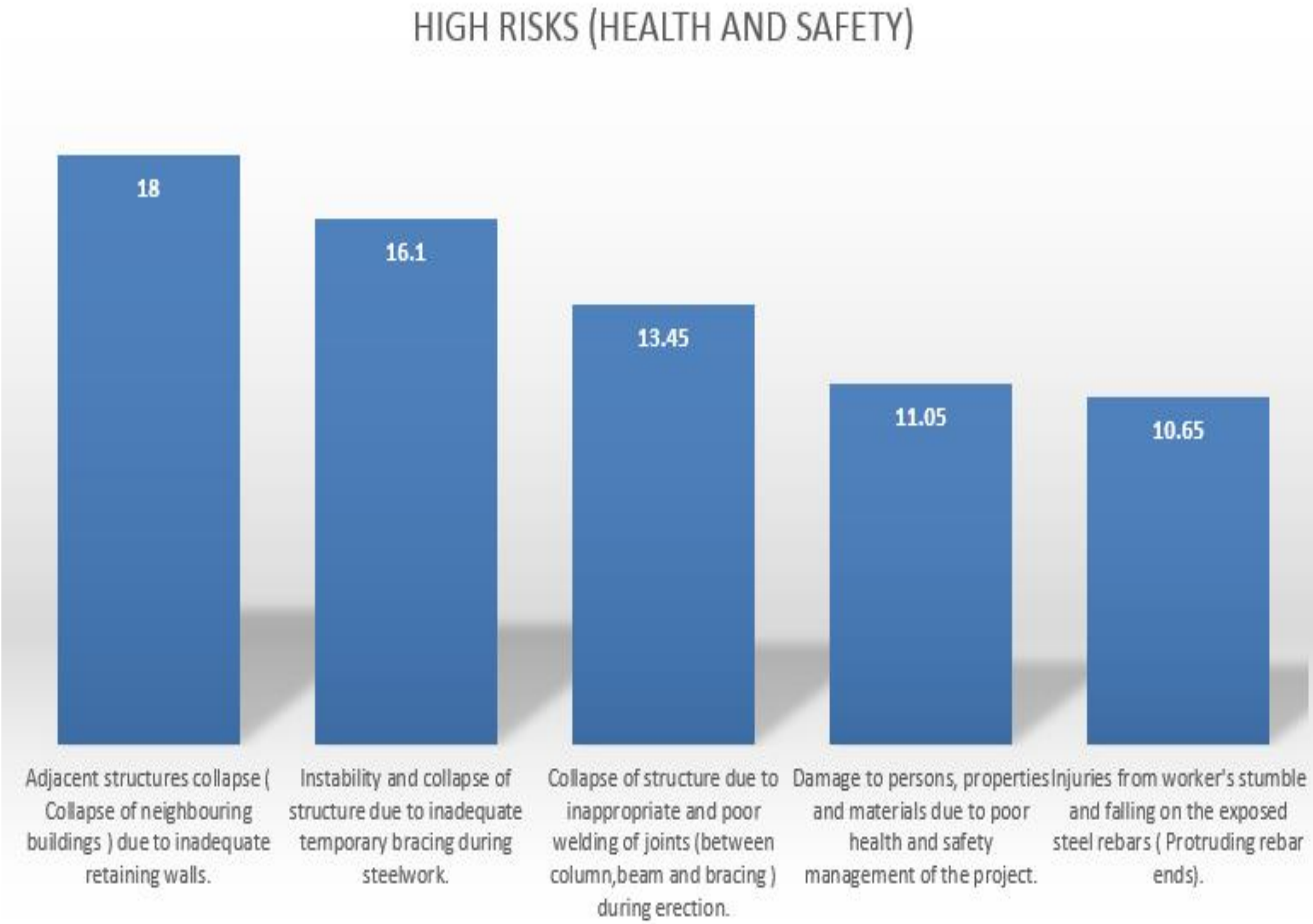

Figure 4.24: Critical risks of health and safety

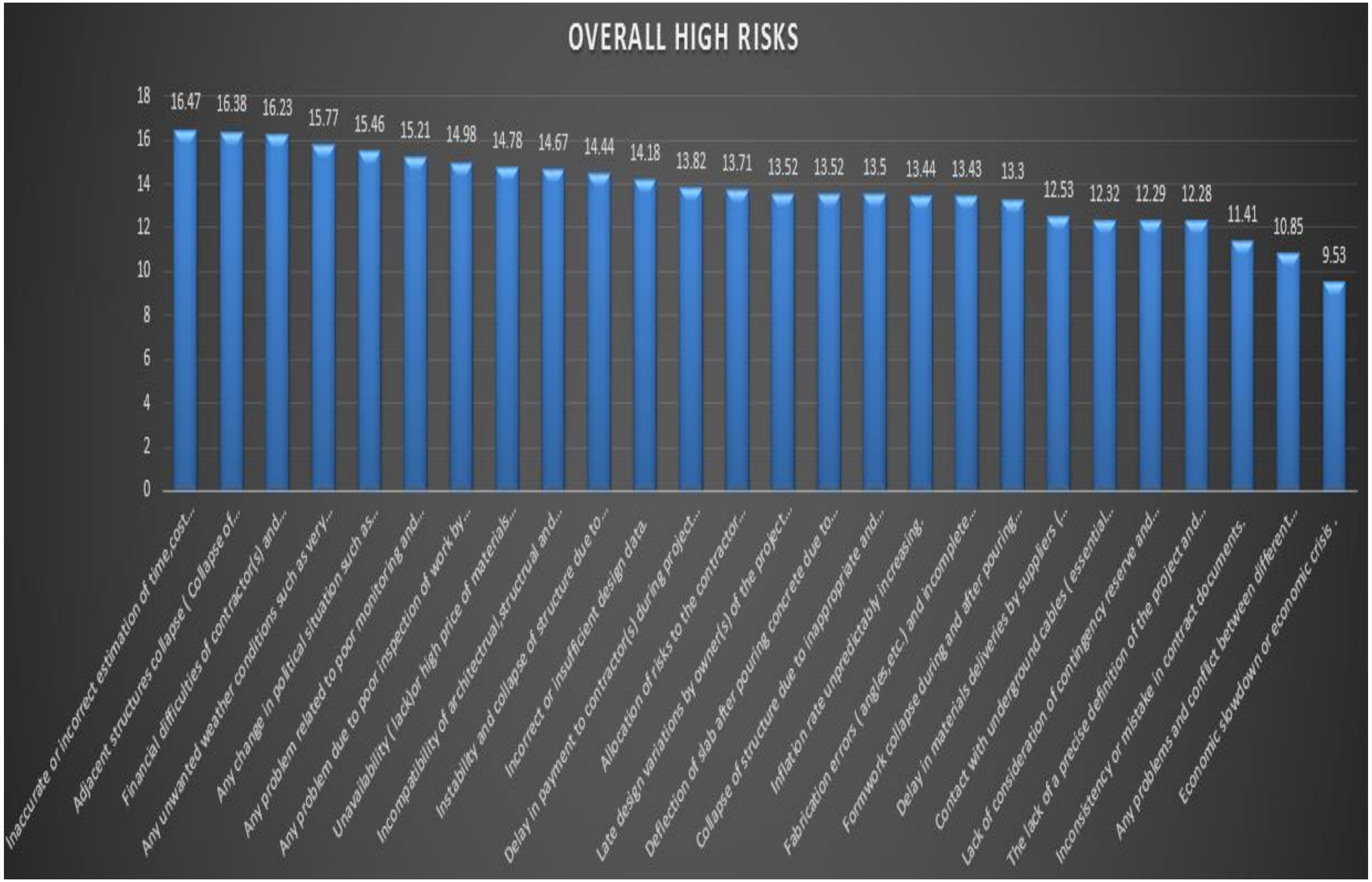

Figure 4.25: Overall high risks

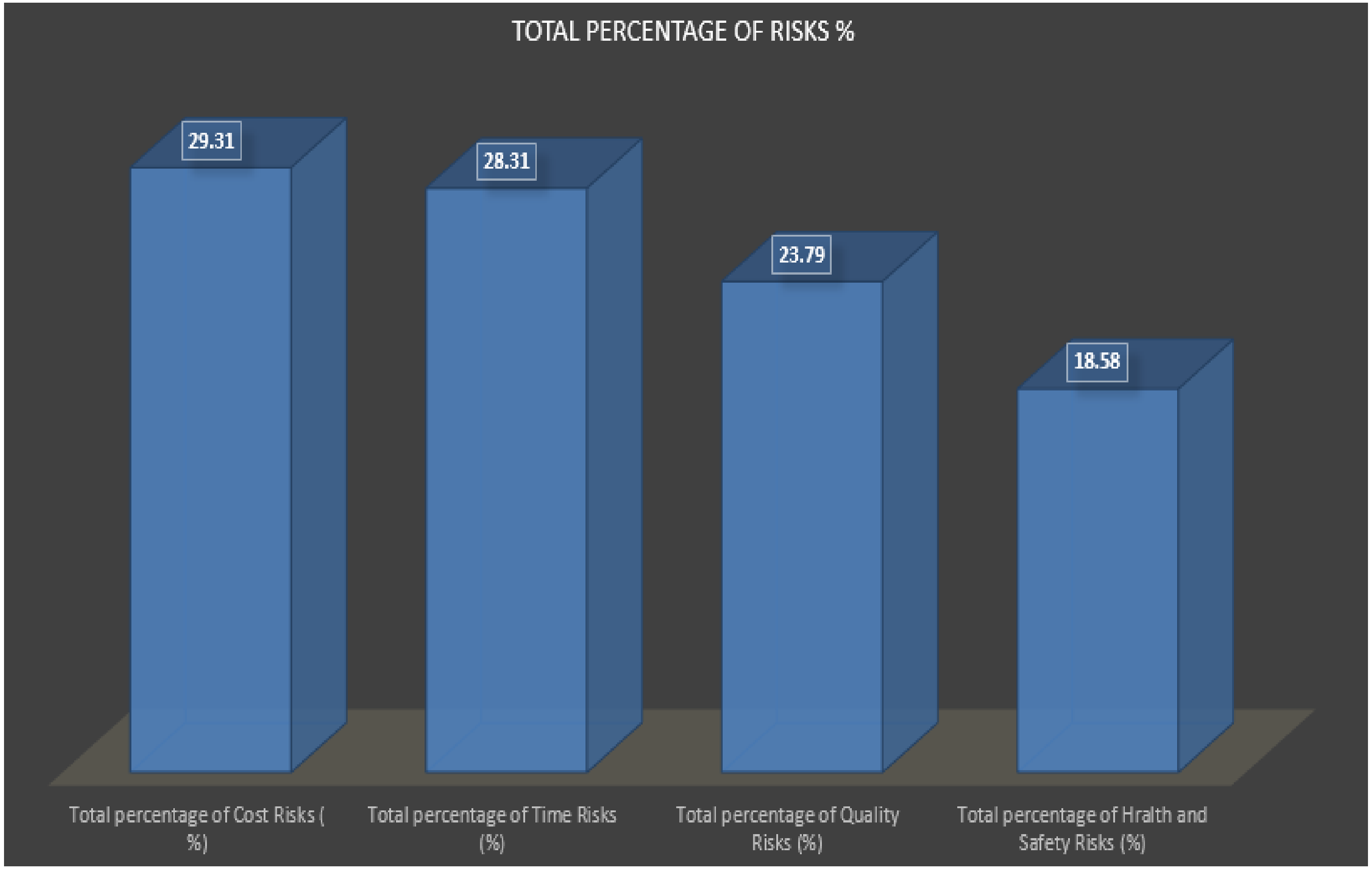

Figure 4.26: Comparison between total percentages of risks

According to the analysis of probability and impact matrix (PIM), it is revealed that the risk of “Inaccurate or incorrect estimation of time, cost and resources in accordance with WBS” has the most influential impact on time of the construction project. In addition, “Unavailability (lack) or high price of materials due to economic conditions in project region or country”, “Any change in political situation such as sanction, etc.”, “Adjacent structures collapse (Collapse of neighboring buildings) due to inadequate retaining walls” are the most critical risks on the cost, quality, health and safety of the construction project, respectively. The overall highest critical risk was also found to be the “Inaccurate or incorrect estimation of time, cost and resources in accordance with WBS”.

Considering these results, the appropriate decision-making about the responses to these risks will be explained in the next chapter.

Chapter 5

RESULTS AND DISCUSSIONS

5.1 Introduction

Outcomes of checklists and questionnaire survey will be broadly explained and discussion will be made accordingly, in this chapter. In one section of this chapter, reasons of threats occurrence will be discussed and recommendations will be made about the possible responses to certain identified threats of high risks, which have been analyzed previously. These strategies have been developed to respond different high risks, which have probable impacts on the projects' objectives (time, cost, quality, and health and safety). Hence, when appropriate responses are developed, contractors and owners can employ these strategies to manage the risks practically.

5.2 Outcomes of Qualitative Analysis

In this study, results of a research work obtained from checklists and questionnaire survey carried out in Iran will be presented and discussed. Having done the analyses, 30 crucial risks, in terms of time, costs, quality, and health and safety, which are the objectives of projects, could be recognized. It should be explained that although the total net number of risks is 30, this amount is the distinct number of risks, considering the common risks, between the objectives. Without considering the mutuality, crucial risks of each objective of time, cost, quality, and health and safety are; 27, 27, 21 and 5, respectively. These risks were identified in the first step and then their impact was evaluated by means of a broad qualitative method of determining their probability and impact magnitudes on the objectives.

According to the results of qualitative analysis of the risks, it was revealed that the most critical risks (with the largest negative impacts) are those affecting the projects' costs. Time and quality risks stand in the next steps and in the last step, health and safety risks are placed.

Moreover, according to the rankings, inside each of these objective categories, there are also single risks revealed to be the most crucial ones. Meaning that, in the category of time, "Inaccurate or incorrect estimation of time, cost and resources in accordance with WBS" was found to have the most negative impact. Similarly, "Unavailability (lack) or high price of materials due to economic conditions in project region or country" was the most critical risk relevant to the cost of projects. In the same way, for the two categories of quality and health and safety, the two risks of "Any change in political situation such as sanction, etc." and "Adjacent structures collapse (Collapse of neighboring buildings) due to inadequate retaining walls" were the most critical ones, respectively. At last, comparing these high ranked risks, the most critical risk, having the highest overall impact on Iran's construction projects was found to be "Inaccurate or incorrect estimation of time, cost and resources in accordance with WBS".

It is interesting to add that the previous researches, conducted in different countries and regions, show different results depending on their cases and conditions with different risk and threats. As an example, in an investigation about construction projects in China, it was found that "Tight project schedule" has the highest negative influence (Zou et al., 2007).

5.3 Outcomes of Questionnaire Survey

During the questionnaire survey, it was observed that some of the participants in the survey were not familiar with the structured techniques of risk management.

Instead, the companies mostly reverted to their previous experiences, discussed about them and tried to benefit from some partnership techniques such as brainstorming, etc. In this cases, regular meeting is organized with the project members and discussions are held to identify, document and categorize risks based on their type. Consecutively, when it is time to evaluate and prioritize the risks, similarly the majority of the investigated companies did not have any experience of utilizing official risk analyses and management methods (such as qualitative and quantitative analysis) and in fact, most of them evaluated the risks' impacts based on their experiences, judgments and perceptions. Only few companies used some formal risk analysis and management techniques, such as probability and impact matrix and Monte Carlo Simulation. The participants' answers to the questionnaire are given in Appendix D.

It is worth explaining that the majority of investigated companies' members explained that lacking time and cost resources are the two main reasons of not employing the structured risk management methods in the projects. These given explanations are also in accordance with what Lynos and Skitmore (2004) found in their investigations about the reasons of not adopting these methods.

5.4 Risk Response Strategies

As it is explained in various references, those risks that are determined to have high impacts and are critical should be faced with a proper response planning to reduce the negative impacts of them to the least possible level (PMI, 2013).

As it was also explained previously, it is revealed from the questionnaires and surveys that most of the participated companies do not have enough knowledge about risk management and so, no proper and systematic responses to the risks. In fact, only few of the companies employed the method of transferring responsibilities to other parties like insurance companies or subcontractors. A large group of participants also replied that mitigation is the most commonly used method when facing with threats of risks. It is not surprising that in this stage, lack of knowledge was also pronounced.

It is obvious that employment of risk management process is effective only if the suitable response to the risks and their threats are planned and applied. Admittedly, irrelevant responses to the risks will not only mitigate or eliminate the risks' threats, but also will lead to excessive time and cost consumptions, while the main threat is still remained and will threaten the project until a proper response technique is chosen, planned and appropriately applied.

Once a risk event is categorized and the proper response is selected, manager of the project will assign a risk owner, who is a stakeholder and could also be a member of project with a special knowledge or experience about risks handling. The risk owner is actually assigned to watch for triggers of risks, to take the proper actions at the right time, be responsible for the execution of plans and involve in creating contingency or fallback plans.

The following outlined strategies are provided separately including specific high risks and their suggested responses and an explanation of why the responses are appropriate.

Lastly, it is crucial to have different project parties involved in project, working cooperatively together and consider proper responses to different risks in order to obtain a feasible, time-efficient and effective management of risks.

5.4.1 "Delay in contract issue by owner of the project"

Strategy: Avoid

This Risk is related to the contract phase, which might be due to work engagement of project owner. The best response is to avoid such risks by assigning someone who can prepare or issue the contract on behalf of the owner.

5.4.2 “Inconsistency or mistake in contract documents”

Strategy: Avoid

This risk is usually occurred in the contract stage as a result of owner’s weakness in management or lack of knowledge. This risk has to be avoided and to do so, the owners have to benefit from a knowledgeable team to prepare the contract documents efficiently and successfully.

5.4.3 “Allocation of risks to the contractor(s), subcontractor(s), owner(s), consultant(s), designer(s), etc. is not mentioned or is not clear in the contract”

Strategy: Avoid

Another risk that happens in the contract stage and has to be avoided is unclarified allocation of risks to different stakeholders. Preventing from this risk is the suggested method which can be done before issuing the contract, through negotiations between different sides of contract.

5.4.4 “The lack of a precise definition of the project and defects in the project documents such as project charter, project scope statement, etc.”

Strategy: Avoid

This risk occurs in the design phase of the project, caused by the weakness of project sponsors or initiators. When the scope and the description of project are not precise and sufficiently detailed, it is indeed an additional negative risk to become involved.

The best response to this risk is to avoid it simply, through establishing and fixing an experienced and knowledgeable team to prepare project documents efficiently and specifically.

It is necessary to explain that project charter is the document that is issued by the project initiator approving the project existence and assigning the project manager who will allocate and employ the necessary resources. Moreover, project scope statement is an in-detailed explanation about the project scope, its aims, products, limitations and expectations. It also includes the works demanded to deliver the products of the project.

Although they seem to resemble each other, there are differences between the levels of details included in them. Project charter mainly contains high-level information about the project; while project scope statement is a comprehensive scope description of project (PMI, 2013).

5.4.5 "Inaccurate or incorrect estimation of time, cost and resources in accordance with WBS"

Strategy: Mitigation

Inaccurate time estimation is also another risk which occurs in design phase. Mitigation is the best known method of facing with this risk, which can be done through benefitting from experts and experienced designers in early stages of project to decrease the gap between the proposed and real time schedule, as much as possible.

Similarly, inaccurate cost estimation also occurs in design stage. This risk is relevant to the designers and consultants of the project and their level of experience and knowledge. It is also likely that due to some changes in policies, unexpected risks occur during the project such as the fluctuation of market prices and rigid cost estimation methods, resulting in deviation of real costs from what expected. Choosing experienced, responsible experts to estimate the costs as accurate as possible and make the contractors involved in the early stages of project can improve accuracy of cost estimation.

Finally, another similar risk is inaccurate estimation of project resources, again occurring in design stage; where by benefitting from experienced designers in early stages can result in a better estimation and decrease the gap between the reality and estimations.

5.4.6 "Incompatibility of architectural, structural and mechanical, etc. plans"

Strategy: Avoid

Another risk in the design stage is incompatibility between different plans, i.e. architectural, mechanical and etc. This risk should be avoided which can be simply done by scheduling meetings between the designers and letting them corporate during the design process.

5.4.7 "Incorrect or insufficient design data"

Strategy: Mitigation

Again in the design stage of the project, this risk may occur which should be mitigated and the probability of its occurrence should be minimized. To do so, it is essential for the design team to well-understand the owners' demands and arrange comprehensive site investigations to obtain reliable design data and establish an efficient communication scheme among the designers.

The designers should involve contractors and owners in reviewing the design drawings in order to minimize design defects.

5.4.8 "Unavailability (lack) or high price of materials due to economic conditions in project region or country"

Strategy: Transfer / Active Acceptance

This risk, which is related to the resources category, is mainly about fluctuating the resources' availability or their prices. It is known that the price of construction materials, which is a large portion of construction costs, is dependent on their supply and their demands and as a result of changing the economic conditions, the prices are not constant. As this risk is more or less inevitable in the projects, a suitable type of contract like lump-sum must be chosen by the owners to transfer the risks to other involved sectors. It is well-accepted that the contractors should always avoid contracts with fixed prices. Along with this point, the best-known strategy is to accept the risks and mitigate their impacts by considering extra costs in cost estimations and including them in bid as well.

5.4.9 "Any problem related to poor monitoring and controlling the quality of tasks execution in project"

Strategy: Mitigation

From its title, it is clear that this risk is related to the category of management risks. Proper strategy against this risk is to mitigate it by having systematic persistent site inspection, monitoring and controlling the effectiveness of the implementations.

5.4.10 "Damage to persons, properties and materials due to poor health and safety management of the project"

Strategy: Mitigation

This risk is also relevant to the management category of the risks. It is necessary to mitigate and minimize the probability of its occurrence by employing a health and safety director to monitor and control the health and safety level of project. All contractor employees should also be trained about the safety knowledge and build safe work method statement for the major construction stages. This requirement must be fulfilled by the health and safety director. Moreover, the safety regulations must also be implemented strictly and effectively by the contractors.

5.4.11 "Schedule compression techniques such as fast tracking and crashing may result in increased risk"

Strategy: Mitigation

Belonging to management category risks, this risk usually occurs in the projects with constricted schedule when some programs need to be reduced to meet the project timeline. In these cases, it is necessary to hire a knowledgeable designer with special experience in minimizing the probability of time schedule compression techniques and help owners produce an appropriate project schedule.

5.4.12 "Lack of consideration of contingency reserve and management reserve in estimating cost and time of the project to encounter with known-unknown and unknown-unknown risks"

Strategy: Mitigation

Reserve is defined as the amount of time or cost which is added to the project and has two main types; contingency reserve and management reserves. Contingency reserves are mainly related to the known unknown such as recognized residual risks that remain after risk response planning.

Management reserves mainly deal with unknown unknowns such as unrecognized risks. Addition of reserves to time and costs of a project is necessary and is part of a specialized project manager's professional responsibility. To mitigate it, it is crucial to choose an experienced project manager.

5.4.13 "Delay in payment to contractor(s) during project implementation phase"

Strategy: Avoid

This risk is placed at the project implementation phase and the best technique is to avoid it simply by working with the owners who are financially stable and have a desirable past records of payment.

5.4.14 "Any problem due to poor inspection of work by contractor (technical mistakes, etc.) during implementation phase"

Strategy: Mitigation

This risk also belongs to the implementation phase of the project and the best method to face with it is to mitigate it through clarifying the responsibilities of different sectors involved in the project, i.e. contractors, subcontractors, etc., and have fixed unchangeable site inspections and meetings to identify projects issues and find solutions.

5.4.15 "Any problems and conflict between different partners of the project"

Strategy: Mitigation

This risk produces chaos and confusions in the management, construction team and programs. Mitigation strategy is suggested to be considered and to do so manager of the project should be appropriately involved in and build up a strong sense of cooperation, trust and communication between project partners.

5.4.16 "Financial difficulties of contractor(s) and owner(s) of the project (problems to provide project funds on time)"

Strategy: Mitigate

This risk, which is mainly related to the stakeholders of the project, is often caused by luxury design, inaccurate assessment of project planning and forecasting at the feasibility stage, which create problems in providing enough budget and may even result in project failure.

A main funding source for the projects is pre-selling the units and properties. In this case, when the market requirements are not predicted exactly, funding shortage will occur. It is reasonable that in the feasibility and design phases, strategic plans and project forecasts should be prepared practically and also, the designs must be financially affordable for the owners. In addition, during the construction, an appropriate distinct plan must be prepared by the owners along with considering a contingency fund, a beforehand standby cash flow, and controlling the cost and timetable. Finally, to mitigate the risks, the last alternative is entering into a fixed loan contract with lending banks, in addition to regular monitoring and controlling the status of the risks.

On the other hand, it is usual for the contractors to assign their labor, resources, budget and etc. to diverse projects to maximize their profit. Bearing this in mind, without being an expert in management, managing the allocation of resources to several constructions projects will not be possible for the contractors. Consequently, an accurate approximation of financial issues and resources capacities must be done to ensure the payments.

5.4.17 "Late design variations by owner(s) of the project or late changes requested by stakeholders"

Strategy: Mitigation/Transfer

Again related to the stakeholders, this risk can straightly result in changes of plan design and construction process. There are two main reasons for these variations, which are the changes of the owners' opinions and wants, and misunderstanding or misinterpreting the owners wants. In the case that the first reason is the cause of risk, the owners should bear the responsibility and the risks must be transferred to the owner. In the second one, mitigation is the suggested technique, which can be done by employing a well-informed designer and initial project team. Through these techniques, the scopes of project and the purposes will be defined clearly, in-detailed investigations on the owner's needs, the construction site conditions will be conducted, and the needs will be adjusted with the restrictions of owner's resources.

5.4.18 "Delay in materials deliveries by suppliers (supplier's incompetency to deliver materials on time)"

Strategy: Mitigation

This risk is also related to the stakeholders of the project and mitigation is the suggested method against its threats. To mitigate this risk, in detailed investigations must be performed at the stage of choosing the resources' suppliers, as there will be long-term collaboration between the project contractor, owners and the suppliers. Considering the designers and contractors' viewpoints, construction materials should be selected according to the market conditions and production cycles. Especially, it is important to consider the geographic location of the materials to avoid long distance transportations.

5.4.19 "Adjacent structures collapse (collapse of neighboring buildings) due to inadequate retaining walls"

Strategy: Mitigation/Transfer

During the earth work stage of a construction project, if any excavation is being performed below the footing level of adjacent buildings, instability of the buildings might occur which may lead to their collapse. To mitigate this risk, skilled designers must also determine the adjacent buildings stability and collapse prevention techniques such as suitable ground support systems (e.g. retaining walls, shoring, etc.) to avoid or mitigate this risk.

Transferring the risks to insurance companies is another method, which is done by construction companies and is mainly meant to prevent starting a reserved fund. These contracts will benefit the companies through multiple coverage of risks, which might occur during the construction process financially and protecting all interested parties.

5.4.20 “Contact with underground cables (essential services) and cutting them during excavation phase”

Strategy: Mitigation

This risk is again related and probable to occur during the earthwork. Mitigation is suggested to be performed against it, which can be done by employing a specific person to take all the necessary information about the underground services in the construction area, along with the essential information of the adjacent sites underground services, before the earth work beginning.

Therefore, it is essential to provide all these necessary information to the contractors of the projects, the excavation contractors and executors, the subcontractors, and all relevant parties of the project.

On the other hand, it is also possible to have inaccuracies in the provided plans of ground services’ information. Considering this inaccuracies, to avoid any possible risks, it is necessary to perform initial examinations on the excavation site (e.g. sampling, etc.).

5.4.21 “Injuries from worker's stumble and falling on the exposed steel rebars (protruding rebar ends)”

Strategy: Mitigation

It is likely that during the reinforcement phase of a construction project, injuries happen to the workers of the construction site. Utilizing a proper health and safety management by the contractor, for example employing protective covers to cover the exposed rebar ends is therefore essential to mitigate this risk.

5.4.22 "Formwork collapse during and after pouring concrete due to inadequate support and low strength to stand the pressure or weight of fresh concrete and vibration pressure, etc."

Strategy: Mitigation

Failure of achieving the right shape accuracy in bowing forms and misalignments and deformations are among the likely events that might happen if this risk is neglected and not mitigated, and may even lead to catastrophic collapse of the whole or a part of the formwork. Choice of span lengths between the studs, and centers between bearers or wales, is necessary to avoid bowing and bulging. This factor together with having a strong enough formwork, against uplift, sliding movement and overturning, is vital and must be precisely controlled.

In short, to have a strong enough formwork, it is vital to have it designed specifically by a competent person to bear the most possible severe load, which might be applied during formwork operations and until the time they are being removed.

5.4.23 "Deflection of slab after pouring concrete due to inadequate and inappropriate props installations, etc."

Strategy: Mitigation

This risk is also one of the risks threatening the formwork phase performance. To mitigate the probability of its occurrence, it is necessary to have all the supports and props untouched and tight in their right location, remaining straightly. Appropriate controlling and supervision during the concrete pouring work will furthermore guarantee the safety from this risks' threat.

5.4.24 "Instability and collapse of structure due to inadequate temporary bracing during steelwork"

Strategy: Mitigation

Associated with the steel structure phase of construction, to mitigate its occurrence's likelihood, assembly of each component of the structure must be performed, only if there is adequate necessary ensuring equipment to guarantee and maintain its safety and stability. One method is to employ temporary bracings to ensure the stability of the whole or a part of the structure. Anchoring the braces must be also done securely accompanied by their regular monitoring, and in the cases of any further risks, extra bracings must be applied.

5.4.25 "Collapse of structure due to inappropriate and poor welding of joints (between column, beam and bracing) during erection"

Strategy: Mitigation

This risk takes place in the phase of steel structure and mitigation is the suggested method of facing with it. To do so, regular inspections of welding joints and checking the stability of members (beams, braces and columns) before releasing the slings must be performed by competent inspectors to ensure about the stability of structure.

5.4.26 "Fabrication errors (angles, etc.) and incomplete fabrication (missing components)"

Strategy: Mitigation

This risk may threaten the project at the stage of steel structure. To mitigate its threats, it is suggested to have regular daily inspections by welding inspectors and employ documented weekly checklists.

5.4.27 "Any unwanted weather conditions such as very cold, very hot, windy, rainy weather and snowy weather"

Strategy: Active Acceptance

The risk is categorized as environmental risk, and it is obvious that they are unavoidable. Therefore, the only method of facing with them is actively accepting them by which it is means that the contactor of project should accept it, and by allocating sufficient contingency in the schedule for such delays in the case of their occurrence, the risk effects should be tried to get mitigated. Moreover, due to the environmental causes, it is necessary for the contactors or owners to provide proper shelters for the working labor and it is also recommended to limit the quantity of materials stored on site as well as place them in safe places.

5.4.28 "Inflation rate unpredictably increasing"

Strategy: Active Acceptance / Transfer

This risk, which is relevant to the economic and financial category of risks, is recommended to be firstly accepted by the contactors, and then its impacts should be mitigated by considering the inflation rate during the cost estimation and including in the bid. Though, in the case of varying unpredictable rates of inflation, transferring the risk to the owner is the suggested method.

5.4.29 "Economic slowdown or economic crisis"

Strategy: Active Acceptance

This risk is also categorized as a financial, economic risk, and should be accepted by contactor. To mitigate the impacts, extra costs must be considered in the cost estimation and should be considered in the bid.

5.4.30 "Any change in political situation such as sanction, etc."

Strategy: Active Acceptance

This risk is considered as a political risk, and it should be actively accepted by the contractors. Moreover, to mitigate the threats of this risk, it is essential to consider extra costs in the cost estimations of the project and include them in the bid.

In the next chapter, conclusions of this research work and the recommended future works will be presented.

Chapter 6

GENERAL CONCLUSION AND RECOMMENDATIONS FOR FUTURE WORKS

6.1 Introduction

In this chapter, the achievements of this research work will be given out briefly along with some recommendations for further studies in this field.

6.2 General Summary and Conclusion

Having a distinguished influence on economy, construction sector is one of the most distinguished sectors of industry, which is also greatly competitive due to large number of companies and relative simplicity of entrance to the sector. Due to its characteristics, this sector is identified as a high risky one and therefore, to minimize the impacts of threats associated with these risks, employing an organized risk management technique is necessary.

Risk management procedure of construction project of a steel-framed structure in Iran, was explored in this research, since this type of structure is more popular in the country. On the other hand, rapid erection in all seasons is achievable only with steel-framed structure buildings. Risk management has been investigated in five different construction work stages, including the earthwork, reinforcement, formwork, concrete work, and steel structure.

In this study, the method of risk identification was a combination of Work Breakdown Structure (WBS) and Risk Breakdown Structure, which resulted in an operative risk identification process in steel-framed structure projects. Furthermore, to collect the necessary data, checklists were prepared and questionnaire survey was performed.

Because of being a user-friendly, cost-effective and rapid, qualitative method of evaluating the identified risks was the selected method to categorize the risks. To perform the method, the probability and impact matrix was the employed technique. The participants in the survey were requested to evaluate the likelihood of risks occurrence and their levels of impact on projects objectives (time, cost, quality, and health and safety) separately, to arrange and classify them along with the overall risk assessment of the project.

After the risk identification and evaluation, it was the time to separate the highly threatening risks, and convey them in the next step, in which decisions would be made about the effective methods of facing with those risks. Specifically about this study, those threatening risks and the responding methods were described thoroughly. It is worth mentioning that these responding methods are suggested only for the highly threatening risks.

The following points are presenting brief achievements of this research:

- Utilizing a combination of Risk Breakdown Structure (RBS) and Work Breakdown Structure (WBS) methods to develop the risk identification more efficiently.
- An entire number of 30 crucial risks were identified and determined, affecting the projects objectives.
- According to the analysis of probability and impact matrix (PIM), it is revealed that the risk of “Inaccurate or incorrect estimation of time, cost and resources in accordance with WBS” has the most influential impact on time of the construction project. In addition, “Unavailability (lack) or high price of materials due to economic conditions

in project region or country", "Any change in political situation such as sanction, etc.", "Adjacent structures collapse (Collapse of neighboring buildings) due to inadequate retaining walls" are the most critical risks on the cost, quality, health and safety of the construction project in Iran, respectively. The overall highest critical risk was also found to be the "Inaccurate or incorrect estimation of time, cost and resources in accordance with WBS". It is worth mentioning that previous researches, conducted in different countries and regions, show different results depending on their cases and conditions with different risks and threats. In other words, the results of risk management will be diverse according to the location and various geographical conditions; thus, a universal integrated standard cannot be implemented for all countries.

- Beside the process of questionnaire survey, it was found that most of the participants (and so the companies) were not familiar with the structured methods of risk management process and instead, their own past methods were still popular and being employed together with some corporation methods such as brainstorming. The unfamiliarity also was extended to the organized methods of evaluating the potential threats, i.e. qualitative and quantitative analysis methods. In short, a large proportion of risk management of the surveyed companies was based on experience, intuition and experience.
- As stated by most of the companies, limited cost and time are main restrictions, preventing risk management methods to be employed.
- Regarding the responding methods to the risks, it was found that a large group of studied companies was not familiar with the formal responding methods. Actually, only a few of the companies employed the responsibility transferring methods to other sectors such as subcontractors and insurance companies to reduce the effect of the

risks. Most of the participants agreed on the controllable nature of the risks and the mitigation strategy is the most commonly employed risk response technique.

• As stated by most of the companies, limited cost and time are main restrictions, preventing risk management methods to be employed.

• Due to the obvious lack of knowledge, in this study, various methods of responding to high risks in terms of the project's objectives have been developed and listed, which are indeed beneficial to the project managers, contactors, owners, and other involved sectors to face with the risks and manage them.

6.3 Recommendations for Future Works

Due to the scope of the present study, all possible issues could not be studied and investigated. Thus, some ideas about future studies are as follows:

1. The technique of risk management will be more efficient and operative, if the companies' culture and also the individuals' viewpoints are improved about the method. This improvement can be done by specific methods, developed through studies and investigations.

2. The structure of risk management technique can be considerably improved, if a blend of qualitative and quantitative methods is employed. In the case of having time and enough data, utilizing simulation techniques such as Monte Carlo Simulation by means of advanced software programs will make additional improvements.

3. Addressing the opportunities associated with the risks along with their threats is another recommendation, which will lead to comprehend the projects objectives and more realistic management.

4. More actions and activities are recommended to be considered in future research works.

5. Further broadening of this research can be done by extending it to other structure types, i.e. concrete and etc.

6. More creative methods are recommended to be developed through further studies to have more productive risk management.

7. Developing and identifying more risk categories are recommended in order to have a more general and broad range of identified potential risks affecting the project objectives, and result in a better and more realistic risk management.

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APPENDICES

Appendix A: Sample of Questionnaire Survey

1. Specify your role in the company (and the project)?

Director Functional manager
Project Manager Site/Office Engineer other

2. Educational and previous experiences qualifications

Education: ________________
Experience in Years ________________

3. How any staffs are involved?

Managerial Staffs: ________________ Technical Staffs: ____________

4. In the past 5 years, how many projects have been executed?

10 Projects or less 11-20 Projects

21-30 Projects 31- 40 Projects More than 40 projects

5. How many years of experience does your company have?

Less than 1 year 1-3 years

3 -5 years 5 -10 years

10 -15 years More than 15 years

6. Are the ideas of risk management and the Risk Management Process, familiar to you?

Yes	No
1	2

7. Is there any risk management program being employed in your organization?

Yes	No
1	2

8. Are the efficient risk management plans considered in your company?

Yes No
1 2

9. Is a distinct projects' scopes usually clarified in your company?

Yes No
1 2

10. Is the schedules of the projects flexible?

Yes No
1 2

11. Is the budget approximation of the project based on the staff experience?

Yes No
1 2

12. Are anticipations of the project from each team member defined clearly, and are in accordance with obtainable resources?

Yes No
1 2

13. Are the staff and management well-understand the objectives of the company and the communication plan entirely?

Yes No
1 2

14. How risks and opportunities are identified in your organization?
Brainstorming Questionnaires Interviews Checklists
Risk Breakdown Structure (RBS)
SWOT methods Delphi methods
Experience and Discussion Databases and past data

15. How do you classify risks?

____

16. What are the basis of risk analyses in your company?

Probability outcome financial impact reputation of the company
Accomplishment of the objectives other, please specify ________________

17. In your company the assessment of risks are based on:

Qualitative analysis Quantitative analysis Both Experience and Intuition

18. Are both external and internal risks addresses in the project plan of the project?

Yes	No
1	2

19. What is the impact level of risk identification, on time, cost and quality and Health and Safety, in the project?

Very High High Moderate Low Very Low

20. To implement the quantitative and qualitative risk analysis, what are the utilized methods, in your company?

Probability and Impact matrix Monte Carlo simulation
Decision tree Sensitivity analysis

21. Who is expected to handle the risks in your company?

Owner (s) Director of Finance Architects Structural Engineers
Consultants General Contractor Risk owners All Staff
Others, please specify ________________

22. Which techniques are usually employed against the risks?

Accepting risks avoiding risks Mitigating risks transferring risks

23. Is an updated risk management plan employed in your organization?

Yes	No
1	2

24. Are the advancements from previous lessons learned employed in your projects?

Yes	No
1	2

Appendix B: Sample of Checklist (English Version)

Name/Surname: Position:

Risk Analysis (RBS &WBS)

Risk Categories				Risk Events	Qualitative Rating for probability & impact (1) Very low (2) Low (3) Modarate (4) High (5) Very high				
						Impact on project			
Level 0	**Level 1**	**Level 2**	**Level 3**		Probability (1-5)	Time (1-5)	Cost (1-5)	Quality (1-5)	Health & Safety (1-5)
Risk		Project	Feasibility(Phase)	Unavailability of needed information,code and standards.					
				Litigation conflict with neighbor of the project.					
				Project Funding difficulties due to bad financial situation of financier (s).					
				Delay of bank in project fund allocation.					
				Poor or incorrect estimation in market,technical & financial analysis.					
				Poor preliminary assessment and evaluation of different possibilities of treatment measures for ground and groundwater.					
			Contract (Phase)	Delay in contract issue by owner of the project.					
				Inconsistency or mistake in contract documents.					
				Any problem or conflict of contractor(s),subcontractor (s),owner (s),project manager and all the stakeholders with contract.					
				Allocation of risks to the contractor (s),subcontractor (s),owner (s),consultant(s),desiner(s),etc is not mentioned or is not clear in the contract.					
				Non standard or inappropriate contract form (type or form of the contract is not standard or compatible with laws).					
			Design & Specification	The lack of a precise definition of the project and defects in the project documents such as project charter,project scope statement,etc.					
				Lack of consistency between bill of quantities ,drawings and specifications.					
				Inaccurate or incorrect estimation of time,cost and resources in accordance with WBS.					
				Incompatibility of architectural, structural and mechanical,etc plans (Not coordinated design).					
				Poor or incorrect technical design due to incorrect or insufficient available information (geological ,geotechnical,..).					
				Design is not appropriate with the project objectives or requirement of the project.					
				Incorrect or insufficient design data.					
				Change in design due to change in design standards during design process.					
				Mistake of designer (s) in calculations ,analysis and evaluations.					
				Delay in presenting design results or design drawing.					
			Resources (Price & Availablity & Quality)	Unavailability (lack)or high price of needed equipments due to economic conditions in project region or country.					
				Unavailability (lack)or high price of manpower due to economic conditions in country.					
				Unavailability (lack)or high price of materials due to economic conditions in project region or country.					
				Poor quality of needed materials,equipment,contractor(s) and subcontractor(s) in project region.					
				Unavailability or lack of needed experts , professional managers and experienced contractors in project region.					
			Management (Project view)	Poor communication in project between different stakeholders.					
				Any problem related to poor monitoring and controlling the quality of tasks execution in project.					
				Any change in management strategies, principles or change of manager(s) of the project,owner(s) and general contractor(s).					
				Applied schedule by inexperienced project manager is not consistent with the desired cost ,scope and quality of the project (inconsistent cost ,time,scope and quality objectives) .					
				Damage to persons, properties and materials due to poor health and safety management of the project.					
				Schedule compression techniques such as fast tracking and crashing may result in increased risk.					

Project	Internal Risk			Lack of consideration of contingency reserve and management reserve in estimating cost and time of the project to encounter with known-unknown and unknown-unknown risks.					
				The project organization chart has not sufficient detail to identify the key personnel and their roles and responsibilities.					
				Scope creep.					
			Implementation	Delay in payment to contractor(s) during project implementation phase.					
				Strike during implementation phase.					
				Delay of contractor in final billing presentation due to poor performance of personnel.					
				Irregular or inadequacy of site inspection by consultant(s) during implementation phase.					
				Any problem due to poor inspection of work by contractor (Technical mistakes ,etc)during implementation phase.					
			Project Stakeholders	Skill deficiency of project manager(s),contactor(s),subcontractor(s),owner(s),consultant(s) ,etc in internal management.					
				Delay in approving the contractor(s) work by consultant(s) or owner(s) of the project.					
				Incompetency of contractor/subcontractor due to lack of experience,equipments ,enough qualified experts and labors.					
				Any problems and conflict between different partners of the project.					
				Financial difficulties of contractor(s) and owner(s) of the project (Problems to provide project funds on time) .					
				Late design variations by owner(s) of the project or late changes requested by stakeholders .					
				Delay in decision making of the project by inexperienced owner(s).					
				Project manager and functional manager(s) to resign.					
				Delay in materials deliveries by suppliers (Supplier's incompetency to deliver materials on time).					
			Activity A (Earth work)	Adjacent structures collapse (Collapse of neighbouring buildings) due to inadequate retaining walls.					
				Landslides due to hard rains during excavation phase which may lead to collapse of neighbouring buildings.					
				Ground collapse.					
				Collapse of excavation sides due to instability of excavation.					
				A person being trapped by the collapse of an excavation.					
				Excavation machinery falls from unprotected edges (Machinery crashes).					
				Manpower's falling into an excavation.					
				Contact with underground cables (essential services)and cutting them during excavation phase.					
				Exposure to underground water during excavation.					
			Activity B (Reinforcement)	Injuries from worker's stumble and falling on the exposed steel rebars (Protruding rebar ends).					
				Heavy lifting of rebar is a potential risk factor.					
				Corrosion of steel rebars.					
				Injuries from cutting and bending rebar.					
				Manpower's slip and fall into reinforcement mesh (Slips & Trips).					
				Manpower's damage by reinforcement wire and rebar 's sharp edges .					
				Back bending and high hand force with repetition and awkward posture while tying rebars.					
			Activity C (Formwork)	Formwork collapse during and after pouring concrete due to inadequate support and low strength to stand the pressure or weight of fresh concrete and vibration pressure,etc.					
				Falling objects from height.					
				Manpower's falling from edges of formwork frames during their erection.					
				Safe working load exceeded during lifting equipments and materials such as lumber,plywood,forms ,etc (Heavy lifting).					

	Activities	(Formwork)	Deflection of slab after pouring concrete due to inadequate and inappropriate props installations,etc.					
			Injury from manually handling the form ply sheets.					
			Collapse of slab due to early removal of the forms,props,etc.					
			Injury of worker's due to slip onto form ply sheet (Slips & Trips).					
		Activity D (Concrete Work)	Collapse of fresh concrete container (bucket,barrow,etc.) during pouring operations.					
			Delay in delivery of ready mixed concrete during pouring concrete.					
			Failure of support systems or platform during pouring concrete.					
			Concrete cracks (Types of concrete cracks such as shrinkage crack,Tension crack ,etc).					
			Contact of wet concrete with eyes and skin during pouring concrete.					
			Manpower's falling down from openings or void spaces&ducts and edge of the work area .					
			Back bending due to hand troweling and manual screeding during pouring concrete (Slab & Foundation).					
			Being struck by objects (equipment & materials) such as concrete buckets.chutes,etc.					
		Activity E (Steel Structure)	Instability and collapse of structure due to inadequate temporary bracing during steelwork.					
			Collapse of structure due to inappropriate and poor welding of joints (between column,beam and bracing) during erection.					
			Failure of lifting equipments.					
			Being struck by objects such as steel members (fall of construction materials and tools)					
			Probability of fire due to welding operation(Welding spatter,grinding spark in flammable environment).					
			Injury of third parties and workers during steel structure erection.					
			Crane overturn due to overloading.					
			Manpower's falling from the height during erection of steel structure.					
			Collapse of structure due to members failure from temprary loading (Unexpected heavy winds) during erection.					
			Crane slings or chains may be released during erection steel structure erection (columns,beams,etc.)					
			Weld failure due to poor quality or lack of testing.					
			Fabrication errors (angles,etc.) and incomplete fabrication (missing components).					
			Risk of injury from inhalation of toxic gases generated during welding.					
External Risk (Project View)	Environmental Risk	Unexpected Weather	Any unwanted weather conditions such as very cold,very hot,windy,rainy weather and snowy weather .					
		Natural Hazards	Natural disasters such as earthquake,flood,landslide,fire,storm and glacial weather,etc.					
	Country Risk	Economic & Financial	Market fluctuations (Low market demand , change in market demand ,etc).					
			Inflation rate unpredictably increasing.					
			Economic slowdown or economic crisis .					
			Interest rate fluctuation.					
			Exchange rate fluctuation.					
		Political	Any change in political situation such as sanction,etc.					
			Political conflict with other countries.					
		Legal & Regulation	Unwanted changes in laws and standards.					
			Delay of government to issue the project permissions (Requirement for permits and their approval take longer than expected).					

Appendix C: Checklist Result by Respondent 1 (Persian Version)

نام و نام خانوادگی : امین پزشک

سمت و سابقه کار: مهندس مشاور 37 سال

Risk Analysis (RBS &WBS)

دسته های ریسک				رویدادهای ریسک	احتمال وقوع ریسک از 1-5	امتیازدهی کیفی (1) خیلی کم (2) کم (3) متوسط (4) زیاد (5) خیلی زیاد			
						تاثیر ریسک روی پروژه			
سطح 0	سطح 1	سطح 2	سطح 3			زمان از 1-5	هزینه از 1-5	کیفیت از 1-5	ایمنی و سلامت 1-5
			مرحله امکان سنجی	عدم دسترسی به اطلاعات مورد نیاز , کد و استانداردها .	1	2	3	3	2
				درگیری (دعوای) قضایی با همسایه پروژه .	2	4	1	2	1
				مشکلات بودجه پروژه بدلیل موقعیت مالی بد سرمایه گذاران .	3	5	2	2	1
				تاخیر بانک در تخصیص وام به پروژه .	3	2	3	1	2
				برآورد ضعیف یا اشتباه در تجزیه و تحلیل بازار , تجزیه و تحلیل فنی و مالی در مطالعات امکان سنجی پروژه.	2	4	5	3	1
				ارزیابی مقدماتی ضعیف از احتمالات مختلف در سنجش عملکرد و رفتار زمین و آبهای زیرزمینی.	2	3	3	1	1
			مرحله قرارداد	تاخیردر صدور قراردادها توسط مالک پروژه.	2	3	4	1	1
				تناقض یا اشتباه در اسناد قرارداد.	3	3	4	2	1
				مشکلات و درگیری پیمانکاران اصلی , پیمانکاران جزء, مالکین , مدیر پروژه و سایر ذینفعان با قرارداد .	4	2	2	3	1
				عدم ذکر و یا عدم شفافیت تخصیص ریسکها به پیمانکاران اصلی , پیمانکاران جز؛ , مالکین , مشاورین , طراحان و سایر ذی نفعان در قرارداد.	4	3	4	4	1
				غیر استاندارد بودن و نامناسب بودن فرم قرارداد وعدم تطابق با ضوابط قانونی .	2	2	3	2	2
			طراحی و مشخصات	عدم تعریف دقیق پروژه وهمچنین نقص در اسناد و مدارک پروژه از قبیل فقدان منشور پروژه , فقدان بیانیه محدوده پروژه و...	4	4	4	3	1
				عدم تطابق بین متره , نقشه ها و مشخصات پروژه .	3	4	2	2	1
				برآورد نادرست زمان , هزینه و منابع درتطابق با ساختار شکست کار(WBS)	5	4	5	5	2
				عدم تطابق نقشه های معماری , سازه و تاسیسات .	5	4	4	3	1
				طراحی فنی ضعیف یا نادرست بدلیل موجود نبودن اطلاعات فنی کافی و صحیح زمین شناسی و ژئوتکنیکی و ...	2	3	4	2	2
				عدم تناسب طراحی با الزامات واهداف پروژه .	1	3	2	4	1
				نادرست و کافی نبودن اطلاعات و داده های طراحی.	5	3	3	3	1
				تغییرات در طراحی بدلیل تغییر استانداردهای طراحی درطول پروسه طراحی .	2	3	2	3	1
				اشتباه طراحان در محاسبات, تجزیه و تحلیل ها و ارزیابی ها .	2	3	4	4	1
				تاخیر در کشیدن نقشه ها و ارائه آن .	2	4	2	1	1
		پروژه	منابع (قیمت، دسترسی و کیفیت)	در دسترس نبودن (فقدان) و یا قیمت بالای تجهیزات مورد نیاز بدلیل شرایط اقتصادی در منطقه پروژه و یا کشور .	2	2	2	2	1
				در دسترس نبودن (فقدان) و یا قیمت بالای نیروی انسانی مورد نیاز بدلیل شرایط اقتصادی کشور .	3	2	3	3	1
				در دسترس نبودن (فقدان) و یا قیمت بالای مصالح ساختمانی مورد نیاز بدلیل شرایط اقتصادی در منطقه پروژه و یا کشور .	5	4	5	4	1
				کیفیت پایین مصالح ,تجهیزات, پیمانکاران اصلی و فرعی مورد نیاز در منطقه پروژه.	2	3	3	3	2
				در دسترس نبودن (فقدان) نیروی متخصص مورد نیاز , مدیران حرفه ای و پیمانکاران با تجربه در منطقه پروژه .	1	4	3	4	2
				ارتباطات ضعیف ذی نفعان مختلف در پروژه.	3	3	4	3	1
				هر گونه مشکل مربوط به نظارت وکنترل ضعیف بر کیفیت اجرای فعالیتها در پروژه .	4	4	4	4	2

ریسک پروژه Project Risk	ریسک داخلی Internal Risk		مدیریت	هر گونه تغییردراصول و استراتژیهای مدیریت ویا تغییر مدیران پروژه , مالکین و پیمانکاران اصلی .	2	1	3	2	2
				عدم تطابق برنامه زمانبندی بکاربرده شده توسط مدیر پروژه بی تجربه با هزینه, محدوده و کیفیت مورد نظر .	3	3	3	4	1
				آسیب به اشخاص, دارایی ها و مصالح پروژه بدلیل مدیریت ضعیف سلامت و ایمنی .	2	4	3	3	4
				افزایش ریسک پروژه بواسطه بکارگیری تکنیک های فشرده سازی زمان بندی از قبیل fast tracking ,Crashing ,...	2	3	4	4	2
				درنظر نگرفتن اندوخته های احتیاطی واندوخته های مدیریتی درمحاسبات زمان وهزینه پروژه برای مقابله و رویارویی با ریسک های نامعلوم شناخته شده و نا معلوم های ناشناخته .	5	3	5	4	1
				کافی نبودن جزئیات چارت سازمانی پروژه جهت شناسایی و مشخص نمودن کارکنان کلیدی و نقش ها و مسئولیت های آنها .	2	2	2	2	2
				خزش محدوده (گسترش تدریجی محدوده پروژه بدون تایید رسمی ویا تغییرطرح مبنای پروژه .	1	2	3	3	1
			اجرا	تاخیردر پرداختها به پیمانکاران پروژه درمرحله اجرا .	5	3	3	4	1
				اعتصابات و اعتراض های کارگری درمرحله اجرا .	2	2	2	2	3
				تاخیر پیمانکاردرارائه صورت وضعیت ها بدلیل عملکرد ضعیف پرسنل .	3	1	2	2	1
				بازرسی نامنظم و ناکافی مشاورین ازسایت پروژه درمرحله اجرا .	2	3	3	3	1
				هرگونه مشکل بدلیل بازرسی ضعیف پیمانکار از کارهای پروژه درمرحله اجرا از قبیل اشتباهات فنی و ...	4	4	5	3	2
			ذی نفعان پروژه	کمبود مهارت مدیران پروژه , پیمانکاران اصلی و فرعی , مالکین و مشاورین و... در مدیریت داخلی .	1	4	3	4	4
				تاخیردرتصویب وتایید کار پیمانکاران توسط مشاورین ومالکین پروژه .	2	2	4	1	2
				بی کفایتی وعدم صلاحیت پیمانکار اصلی و جزء بدلیل بی تجربگی وکمبود تجهیزات, کارگران ومتخصصین واجد شرایط .	2	3	4	4	3
				هرگونه درگیری ومشکلات بین شرکای مختلف پروژه .	3	5	3	5	2
				مشکلات مالی پیمانکاران ومالکین پروژه وعدم تامین به موقع منابع مالی پروژه .	5	4	5	5	2
				تغییرات دیرهنگام درنقشه ها توسط مالکین پروژه ویا درخواست های تغییرات دیرهنگام توسط ذی نفعان پروژه .	4	3	3	2	2
				تاخیردرتصمیم گیریهای پروژه توسط مالکین بی تجربه .	4	3	2	1	1
				استعفای مدیر پروژه ومدیران وظیفه ای .	3	4	4	3	2
				تاخیردرتحویل مصالح توسط عرضه کنندگان وتامین کنندگان کالا (عدم صلاحیت تامین کنندگان کالا در تحویل به موقع مصالح)	3	5	3	3	1
			عملیات خاکی	سقوط ساختمانهای مجاور (سقوط ساختمانهای همسایگان) بدلیل کافی نبودن دیوارهای حائل .	4	4	4	4	5
				رانش زمین بدلیل بارانهای شدید در زمان خاکبرداری که ممکن است به سقوط ساختمانهای همسایه منجر گردد .	2	3	5	2	5
				سقوط و فروپاشی زمین .	1	3	2	1	3
				سقوط ترانشه وکناره های خاکبرداری بدلیل ناپایداری خاکبرداری .	2	2	4	3	4
				گیرافتادن اشخاص بواسطه سقوط خاکبرداری .	1	2	4	1	5
				افتادن ماشین آلات خاکبرداری از لبه های محافظت نشده کار.(سقوط ماشین آلات حفاری)	2	3	3	1	3
				افتادن نیروی انسانی به داخل خاکبرداری .	2	3	2	1	3
				برخورد با کابلهای زیرزمینی (خدمات ضروری) و قطع کردن آنها درحین خاکبرداری .	4	3	3	2	1
				قرار گرفتن در معرض آبهای زیرزمینی درطول زمان خاکبرداری .	2	2	3	1	1
				صدمات ناشی از لیز خوردن کارگران و افتادن بروی میلگردهای بیرون زده از کار .	3	3	4	2	5
				بلند کردن میلگردهای سنگین .	1	2	1	1	3
				خوردگی میلگردهای فولادی .	2	1	2	3	1

67				آرماتوربندی	صدمات ناشی از بریدن وخم کردن میلگرد .	2	1	3	1	2
68					لیزخوردن نیروی انسانی و افتادن در شبکه آرماتور (فونداسیون) .	2	1	3	2	3
69					آسیب نیروی انسانی ناشی ازسیم آرماتوربندی ولبه های تیزآرماتور .	2	1	2	2	3
70					خم شدن بیش ازاندازه و وارد شدن نیروی بیش ازاندازه به دستها در زمان بستن میلگردها .	2	2	2	2	2
71					فروپاشی و بازشدن قالب ها درطول و بعد از ریختن بتن بدلیل تکیه گاه ناکافی ومحکم نبودن قالب ها برای تحمل فشار و وزن بتن تازه و فشار ویبراتور و...	5	3	3	4	3
72					افتادن اشیاء ازارتفاع .	4	3	3	2	3
73					افتادن نیروی انسانی از لبه های چهارچوب قالب بندی در زمان نصب قالب ها .	1	3	4	2	5
74				قالب بندی	فراتر رفتن بار کاری ایمن در زمان بلند کردن تجهیزات و مصالح از قبیل الوار, تخته سه لا, قالب ها و ...	1	2	4	1	3
75					انحنا و خمش سقف (شکم کردن) بعد از ریختن بتن بدلیل نصب ناکافی و نامناسب شمع ها .	4	2	3	5	2
76					آسیب های ناشی از لمس دستی ورقه های تخته چندلا .	1	2	2	2	3
77			فعالیت ها		سقوط سقف به علت برداشتن و بازکردن زودهنگام قالب ها و شمع ها و...	1	4	4	3	5
78					آسیب ناشی از لیزخوردن کارگران بر روی صفحه های تخته چندلا .	2	2	2	2	4
79					سقوط حمل کننده های بتن تازه از قبیل باکت ها و گاریها و...درطی عملیات ریختن بتن .	3	1	2	2	3
80					تاخیر در تحویل بتن میکس شده آماده در طول عملیات ریختن بتن .	2	2	3	3	2
81					شکست و فروپاشی سیستم های پشتیبان و کف (بستر) کار درطول عملیات بتن ریزی .	2	3	2	4	4
82					انواع ترک های بتن از قبیل ترک های انقباضی و ترک های کششی و...	3	3	4	2	1
83				بتن ریزی	تماس بتن مرطوب و تازه با چشم ها و پوست بدن درطول عملیات ریختن بتن .	2	2	2	1	2
84					افتادن و سقوط نیروی انسانی از فضاهای خالی و محل داکت ها و لبه های محل کار .	1	3	3	1	5
85					خم شدن بیش از اندازه بدلیل کشیدن شمشه و ماله دستی درطول عملیات ریختن بتن (سقف, فونداسیون) .	3	2	3	2	1
86					مورد اصابت قرارگرفتن توسط اشیاء (تجهیزات و مصالح) از قبیل باکت ها و شوت های بتن ریزی .	2	2	4	1	3
87					ناپایداری و فروپاشی (سقوط) سازه بدلیل ناکافی بودن بادبندهای موقتی در زمان اجرای اسکلت .	4	5	4	3	3
88					فروپاشی و سقوط سازه بدلیل جوش نامناسب وضعیف مفاصل (تیرها , ستونها و بادبندها) در زمان نصب سازه فلزی .	3	5	5	3	5
89					شکست و سقوط تجهیزات بالابرنده از قبیل بالابر و ...	2	2	4	2	3
90					مورد اصابت قرار گرفتن توسط اشیاء از قبیل اجزاء فولادی سازه و ...(افتادن مصالح و ابزارهای ساختمانی).	2	1	3	2	3
91					احتمال آتش سوزی بدلیل عملیات جوشکاری (پاشش جوش و جرقه ناشی از سنگ زنی در محیط قابل اشتعال).	2	4	2	3	4
92					آسیب اشخاص ثالث و کارگران درطول نصب سازه فلزی .	3	1	2	1	2
93					واژگون شدن جرثقیل بدلیل اضافه بار (باراضافی).	1	3	3	1	2
94				سازه فلزی	افتادن و سقوط نیروی انسانی از ارتفاع درطول نصب سازه فلزی .	1	4	4	1	4

			فروپاشی و سقوط سازه بدلیل شکست و فروپاشی اجزاء سازه در اثر بارهای موقتی از قبیل بادهای شدید غیرمترقبه در زمان نصب سازه .	1	4	5	1	5
			احتمال آزاد شدن قلاب ها و زنجیرهای جرثقیل در زمان نصب سازه فلزی (ستونها , تیرها و...) .	3	3	3	1	2
			شکست جوش بدلیل کیفیت پایین و یا عدم انجام آزمایشات و تست های جوش .	3	3	4	2	1
			خطاهای ساخت (زاویه و غیره) و همچنین ساخت ناقص (از قلم انداختن یکسری از اجزاء).	3	4	5	5	2
			خطر ناشی ازاستنشاق گازهای سمی تولید شده در طول عملیات جوشکاری .	1	1	3	2	2
External Risk (Project View) ریسک خارجی	ریسک زیست محیطی	آب و هوا غیر مترقبه	هر گونه شرایط ناخواسته آب و هوایی از قبیل بسیار سرد, بسیار گرم , بادی , آب و هوای بارانی و برفی وغیره .	5	4	3	2	2
		خطرات و بلایای طبیعی	بلایای طبیعی مانند زلزله , سیل , رانش زمین , آتش سوزی , طوفان , آب و هوای یخبندان و غیره .	2	4	5	3	4
	ریسک مربوط به کشور	اقتصادی و مالی	نوسانات بازار (تقاضای کم بازار , تغییردر تقاضای بازار و...) .	2	3	2	3	2
			افزایش غیرقابل پیش بینی نرخ تورم .	5	3	5	4	2
			کاهش رشد اقتصادی و بحران اقتصادی .	3	4	4	3	2
			نوسانات نرخ بهره .	2	1	3	2	2
			نوسانات نرخ ارز .	2	2	3	3	3
		سیاسی	هر گونه تغییر در وضعیت سیاسی مانند تحریم و ...	4	5	4	4	2
			درگیری سیاسی با کشورهای دیگر .	3	1	1	1	1
		حقوقی و قانون و مقررات	تغییرات ناخواسته درقوانین واستانداردها .	2	4	2	3	1
			تاخیر دولت و مقامات دولتی در صدور مجوز پروژه (فراتر رفتن زمان صدور مجوز پروژه از حد مورد انتظار) .	2	4	2	1	1

Appendix D: Answers to Questionnaire Survey

General Information

1. Respondents 1, 2 and 19 were Consultant; Respondents 3, 5, 7, 10 and 14 were Project manager; Respondents 4, 6 were Site Manager; Respondents 8, 20 were Executive director; Respondents 9, 11 were Site Supervisor; Respondent 12 was Technical Office Engineer; Respondents 13, 16 and 18 were Structural Engineer; Respondents 15, 17 were Supervisor.

2. The job experience of respondent 1 was 37 years master of civil engineering degree. The job experience of respondent 2 was 17 years master of civil engineering degree. The job experience of respondent 3 was 25 years Bachelor’s degree in civil engineering. The job experience of respondent 4 was 12 years Bachelor’s degree in civil engineering. The job experience of respondent 5 was 20 years Bachelor’s degree in civil engineering. The job experience of respondent 6 was 22 years Bachelor’s degree in civil engineering. The job experience of respondent 7 was 15 years Bachelor’s degree in civil engineering. The job experience of respondent 8 was 13 years master of civil engineering degree. The job experience of respondent 9 was 16 years Bachelor’s degree in civil engineering. The job experience of respondent 10 was 32 years Bachelor’s degree in civil engineering. The job experience of respondent 11 was 11 years Bachelor’s degree in civil engineering. The job experience of respondent 12 was 10 years Bachelor’s degree in civil engineering. The job experience of respondent 13 was 9 years with Bachelor’s degree in civil engineering. The job experience of respondent 14 was 14 years with master of civil engineering degree. The job experience of respondent 15 was 13 years with master of civil engineering degree. The job experience of respondent 16 was 8 years with Bachelor’s degree in civil

engineering. The job experience of respondent 17 was 12 years with Bachelor's degree in civil engineering. The job experience of respondent 18 was 7 years with master of civil engineering degree. The job experience of respondent 19 was 16 years with master of civil engineering degree. The job experience of respondent 20 was 11 years with Bachelor's degree in civil engineering.

3. Respondents 1, 3, 5 and 10 had own companies, respondent 1 had 8 managerial employees and 16 technical employees, respondent 3 had 4 managerial employees and 8 technical employees, respondent 5 had 11 managerial employees and 23 technical employees, respondent 10 had 9 managerial employees and 20 technical employees. Other respondents work within companies which had many managerial and technical employees and all the companies was huge and famous.

4. Respondents 1, 2, 3, 5, 6, 10, 14, and 19 declared that execute between 31-40 projects nearly; respondents 4, 7, 8, 9, and 17 declared that execute between 21-30 projects nearly; 11, 12, 13, 15, 16, 18, and 20 declared that execute between 11-20 projects nearly.

5. Respondents 1, 2, 3, 5, 6, 7, 9, 10, 14, 19 were more than 15 years and other organizations had between 10-15 years' experience.

6. Respondents 1, 3, 5, 7, 10 and 14 were familiar with most parts of risk managements but the rest of the respondents do not have a proper insight and knowledge with structured risk management.

7. Except respondent 1, 3, 10 and 14 that had risk management plan in their organization other organization's respondents did not have any plan for risk management.

8. Except respondent 1, 3, 10 and 14 that had risk management plan in their companies other companies' respondents did not consider the presence of efficient risk management plan.

9. Respondents 1, 2, 3, 5, 6, 7, 9, 10, 14, 17, and 19 declared that scope usually well defined in their companies but other respondents had adverse responses.

10. Nearly all the respondents declared that their project's schedules are not flexible except respondents 1, 3 and 10.

11. All the respondents declared that the budget of the project estimate based upon the experience of the staff.

12. Respondents 1, 2, 3, 5, 6, 7, 8, 9, 10, 14, 19 and 20 had positive responses and other responses had adverse responses.

13. Respondents 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 14, 19 and 20 had positive responses and other responses had adverse responses.

Risk Management Process

14. Respondents 1, 2, 3, 5, 7, 10, 14, 19 and 20 declared that they identify risks with brainstorming, checklist, past experience and discussion; other respondents admitted that they identify potential risks with past experience and discussion.

15. Almost all the respondents declared that the most widely tool in order to categorize potential risks is discussing about the risks. Primarily managing the risks are done, within the organization, with regard to the scope of assigned work, managed and consulted afterwards, with the other members of team, but respondents 1, 3, 5, 7, 10 and 14 declared that they used some formal and structured technique such as qualitative analysis besides discussion.

16. Respondents 1, 2, 3, 5, 7, 8, 9, 10, 14, 19, and 20 declared that they analyzed the risks based on accomplishment of the objectives and financial impact and other respondent admitted that they analyzed risks based on financial impact.

17. Respondents 1, 3, 5, 7, 10, and 14 declared that they assess the potential risks with qualitative technique, experience and intuition and other respondent admitted that they assess the risks with their past experience, intuition and judgment.

18. All the respondents had positive responses.

19. Respondents 1, 3, 5, 7, 10, and 14 believed that identify the risks have high effects on project objectives but other respondents declared that it has moderate and low effects on project's objectives.

20. Respondents 1, 3, 5, and 7 declared that they use probability and Impact matrix for qualitative analysis and respondents 10 and 14 admitted that they use Probability and Impact matrix for qualitative analysis and Monte Carlo Simulation for quantitative analysis. Other respondents did not answer to this question.

21. Respondents 1, 2, 3, 5, 7, 10, and 14 declared that project manager is responsible for handling the risks; Respondents 4, 6, 8, 9, 19, and 20 declared that general contractor and structural engineers are responsible for handling the risks; Respondent 12, 13, 15, and 18 admitted that structural engineers and owners should handle the risks and respondents 11, 16, and 17 declared that project manager and general contractor should handle the risks.

22. Respondents 1, 2, 3, 5, 7, 10, 14, 19 and 20 declared that the best response strategies are mitigation which is done through past experience and discussion and also transferring the risks to other parties such as insurance and subcontractors and for some low impact risks acceptance is the best strategy; other respondents admitted that the best response strategy is mitigating the risks.

23. Respondent 1, 3, 5, 10, and 14 had positive responses and other respondents had adverse responses.

24. All the respondents declared that they apply their improvements from previous lessons learned in their projects.

Appendix E: Respondents and Companies Profile

Respondents	Name of Respondents And Company 's Name	Position	Work Experience
Respondent 1	Pezeshk.A. Pouya Tarh	Consultant	37 Years
Respondent 2	Rezaie O. Hasebe Fars	Consultant	17 Years
Respondent 3	Aghaie.R. Mosalas	Project Manager	25 Years
Respondent4	Ramezani M. Taag	Site Manager	12 Years
Respondent 5	Moshkelgosha A. Haraayeh	Project Manager	20 Years
Respondent 6	Peytam N. Ashian Saaz	Site Manager	22 Years
Respondent 7	Tavakol SH. Neysar Saazeh	Project Manager	15 Years
Respondent 8	Taghinezhad M. Sang Beel	Executive director	13 Years
Respondent 9	Bostangol R. Hesaar Beton	Site Supervisor	16 Years
Respondent 10	Meshksar A. Taaraasaa	Project Manager	32 Years
Respondent 11	Rezaie A. Zanjaab	Site Supervisor	11 Years
Respondent 12	Niroomandi M. Dejbor	Technical Office Engineer	10 Years
Respondent 13	Ranjbar O. Peykar Banaa	Structural Engineer	9 Years
Respondent 14	Ghane M. Rahyab Pars	Project Manager	14 Years
Respondent 15	Soroushnia S. Rahgam	Supervisor	13 Years
Respondent 16	Edrisi E. Raazaan	Structural Engineer	8 Years
Respondent 17	Ahmadzadeh A. Omraan Sazeh	Supervisor	12 Years
Respondent 18	Homayoun M. Dejbor	Structural Engineer	7 Years
Respondent 19	Moshkelgosha E. Jaashk	Consultant	16 Years
Respondent 20	Nafezi P. Taashkan	Executive director	11Years

Appendix F: Significance Score Risk

The risk significant index was used in this research, established by (Shen, et al., 2001).

Considering the effectiveness of risks on specific project objectives, the significance score, evaluated by each respondent can be calculated by Equation (1).

$$r_{ij}^{k} = \alpha_{ij}\beta_{ij}^{k} \tag{1}$$

In which; *r* is the significance score of risk *i*, evaluated by respondent *j*, on the project objective *k*. *i* is the ordinal number of risk, varying between 1 to 105; *k* is the ordinal number of project objective, varying between 1 to 4 and *j* is the ordinal number of valid feedback to risk *i, j*= (1, *n=20*); *n* = total number of valid checklists; *α* = likelihood occurrence of risk *i*, assessed by respondent *j; β* = level of impact of risk *i* on project objective *k*, assessed by respondent *j*.

The average score of each risk considering its impact on a specific project objective, can be calculated by Equation (2).

This average score is called the risk significance index score, and will be employed to arrange all risks impacts, on a particular project objective.

$$R_{i}^{k} = \frac{\sum_{j=1}^{n} r_{ij}^{k}}{n} = \frac{1}{n}\sum_{j=1}^{n} \alpha_{ij}\beta_{ij}^{k} \tag{2}$$

In which R is the significance index score for risk i on project objective k. (Average risk score for risk i on project objective k)

Moreover, Equation (3) is employed to obtain the percentages of each risks than other ones, presented as;

$$\text{Rpi}= \frac{Ri}{\sum Rtk} \times 100 \qquad (3)$$

Where Rpi is the Percentage for risk i on project objective *k*; Σ Rtk is standing as the total significance index score on project objective *k* (Total Average risk score on project objective *k*).

Regarding the influence on a specific project objective, the Total percentage of risks can be calculated by Equation (4).

$$\text{Tpr}=\frac{\sum Rtk}{\sum(\sum Rtk)} \times 100 \qquad (4)$$

Where Tpr is the Total Percentage of risks; Σ Rtk represents the total significance index score on project objective *k* (Total Average risk score on project objective *k*).

Appendix G: Respondents' Risk Scores for all identified Risk Events

	Risk Event 1					Risk Event 2					Risk Event 3					Risk Event 4					Risk Event 5				
	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S
Respondent 1	1	2	3	3	2	2	4	1	2	1	3	5	2	2	1	3	2	3	1	2	2	4	5	3	1
Respondent 2	3	2	2	3	4	1	4	2	1	2	2	5	2	3	1	2	3	4	1	1	2	3	3	3	2
Respondent 3	2	3	2	3	3	1	2	1	2	2	3	5	3	1	1	2	2	3	3	1	3	3	3	1	1
Respondent 4	2	2	2	2	4	3	2	2	1	2	2	3	3	2	2	2	3	3	2	2	4	4	3	1	1
Respondent 5	2	4	3	3	3	3	4	1	2	1	2	3	2	3	1	4	2	3	1	1	3	4	3	2	1
Respondent 6	2	2	2	3	4	1	3	1	1	2	2	4	2	2	1	3	2	3	3	2	4	3	5	3	1
Respondent 7	3	3	2	2	4	3	4	2	1	1	2	5	3	2	2	4	2	2	1	1	3	4	5	3	1
Respondent 8	1	3	3	4	2	1	2	1	2	2	1	5	4	3	1	4	2	2	2	1	2	5	5	2	2
Respondent 9	3	2	3	3	4	2	2	1	1	2	3	4	2	3	2	2	2	4	1	2	2	4	5	2	1
Respondent 10	1	2	3	4	3	3	2	2	1	2	3	3	3	3	2	3	2	3	1	2	3	4	4	3	1
Respondent 11	1	3	3	3	2	3	3	2	1	3	3	4	3	3	2	3	3	4	1	1	2	5	3	2	2
Respondent 12	1	2	4	3	3	3	4	1	2	1	1	3	2	3	1	3	1	4	3	1	2	4	5	1	1
Respondent 13	2	4	3	2	4	2	2	1	2	1	3	5	3	3	1	3	2	3	1	2	2	5	4	2	1
Respondent 14	2	2	2	2	3	1	2	2	1	2	2	4	4	2	2	4	2	3	2	1	4	4	3	2	1
Respondent 15	2	3	3	3	4	1	3	1	1	2	1	5	3	2	1	3	2	3	2	2	4	4	4	3	1
Respondent 16	2	3	3	2	4	1	3	3	1	2	2	4	3	3	1	3	2	3	2	2	2	3	4	3	1
Respondent 17	2	4	2	3	3	1	4	1	1	1	3	3	2	2	2	3	2	2	2	1	4	4	3	2	1
Respondent 18	1	4	3	3	4	1	2	2	1	1	2	4	2	2	2	4	1	3	1	1	2	3	3	3	2
Respondent 19	3	3	2	3	2	3	3	2	2	1	3	5	3	1	1	2	2	4	3	1	3	3	4	3	1
Respondent 20	3	2	3	3	3	3	3	1	1	2	3	4	2	3	1	2	3	3	2	1	4	5	3	3	1

Risk Event 6					Risk Event 7					Risk Event 8					Risk Event 9					Risk Event 10					Risk Event 11				
Probabilit	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S
2	3	3	1	1	2	3	4	1	1	3	3	4	2	1	4	2	2	3	1	4	3	4	4	1	2	2	3	2	2
3	2	4	1	1	3	3	2	2	1	5	4	4	2	1	3	2	4	3	1	5	3	5	4	1	4	2	3	1	1
4	3	2	1	1	4	4	3	1	1	4	3	5	3	2	3	2	3	2	1	4	3	4	3	1	2	3	2	1	1
3	3	4	1	2	4	5	3	1	1	5	3	3	2	1	3	3	2	3	1	4	3	5	3	1	3	3	3	2	1
4	3	3	2	1	3	5	4	1	1	3	2	4	3	1	4	3	2	2	1	4	3	5	4	2	4	2	2	1	1
4	3	2	1	1	4	3	3	1	1	5	4	3	4	1	3	2	3	3	2	4	4	5	2	1	2	2	3	3	1
2	4	4	2	2	3	3	3	1	1	4	2	5	3	1	3	3	3	3	1	5	3	5	2	1	2	3	3	2	2
2	4	3	2	1	3	5	4	1	1	5	3	3	2	1	3	4	4	3	2	5	4	5	4	1	3	2	3	2	1
3	3	2	2	1	3	5	3	1	1	4	2	3	3	1	2	2	3	3	1	4	3	5	3	1	3	3	2	1	1
3	3	4	2	1	2	4	3	2	1	4	2	4	4	1	2	2	3	4	1	3	4	4	2	1	2	3	2	1	1
4	2	3	2	1	3	3	4	1	1	4	2	4	3	1	3	3	4	2	1	5	3	4	3	1	3	2	2	2	1
4	2	4	2	1	2	3	4	1	1	5	2	3	4	1	3	2	3	2	2	3	4	5	4	1	2	2	2	3	2
4	2	2	2	1	4	3	3	2	1	3	2	5	3	1	4	3	3	2	1	4	3	3	4	2	3	3	2	2	1
2	2	3	1	1	4	4	2	1	1	3	4	3	2	1	3	2	3	2	2	3	4	5	4	1	4	3	2	1	1
4	2	3	2	2	4	5	3	1	1	3	4	5	3	2	4	2	3	2	1	4	5	3	4	1	4	2	2	3	1
4	2	3	1	1	4	4	3	1	1	4	3	3	4	1	3	3	3	3	2	5	3	4	2	1	2	1	3	2	2
3	3	2	2	2	2	5	3	1	1	5	4	4	2	1	2	4	2	4	2	4	3	5	4	1	2	2	2	3	1
4	2	4	1	1	2	5	2	2	1	5	2	4	2	1	3	4	2	2	2	4	3	5	4	2	4	3	2	1	1
4	3	4	2	1	4	3	2	1	1	3	4	3	3	1	4	3	2	2	1	5	4	3	2	1	4	2	2	2	1
3	3	3	2	1	4	3	2	1	1	5	3	3	3	1	2	2	2	3	2	5	4	5	4	1	4	2	2	2	1

Risk Event 12					Risk Event 13					Risk Event 14					Risk Event 15					Risk Event 16				
Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S
4	4	4	3	1	3	4	2	2	1	5	4	5	5	2	5	4	4	3	1	2	3	4	2	2
5	4	3	3	1	3	2	3	3	1	5	5	5	3	1	4	4	5	4	1	2	4	4	3	2
4	5	3	4	1	3	4	3	3	1	5	5	4	3	1	3	4	4	3	1	3	3	3	4	1
3	5	4	3	1	3	2	2	3	1	5	5	4	4	1	5	4	4	3	2	3	2	4	3	2
4	4	4	3	1	3	4	3	2	1	5	5	5	4	1	4	5	5	5	1	2	4	2	4	1
4	3	4	4	1	3	4	2	3	1	5	4	4	5	1	5	4	3	4	1	2	4	3	3	1
3	4	4	4	1	2	3	3	2	1	5	5	5	5	2	5	5	5	4	1	2	2	4	3	3
3	4	4	2	1	4	3	3	2	1	4	4	3	4	1	4	4	3	4	1	2	3	2	3	1
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4	3	4	3	1	3	2	2	3	1	4	4	3	5	2	4	5	4	5	1	3	4	2	2	3
5	3	3	4	1	4	2	2	2	1	4	5	5	4	1	5	4	3	3	1	4	2	2	2	2
4	5	4	4	1	4	2	2	2	1	4	4	4	5	1	5	4	3	5	1	4	2	4	4	3
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4	4	3	3	1	4	2	2	2	1	4	5	4	5	1	5	4	3	4	2	4	4	2	3	1
4	3	4	4	2	2	2	2	2	1	4	4	4	3	2	4	4	3	4	1	2	2	4	2	2

Risk Event 17					Risk Event 18					Risk Event 19					Risk Event 20					Risk Event 21				
Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S
1	3	2	4	1	5	3	3	3	1	2	3	2	3	1	2	3	4	4	1	2	4	2	1	1
2	2	2	3	2	3	3	3	3	1	2	3	2	3	1	2	2	3	4	2	3	2	2	1	1
1	3	4	3	1	3	4	5	4	1	3	3	3	2	1	4	3	2	3	1	3	3	2	1	1
1	4	3	3	1	5	3	4	3	1	3	4	2	2	1	3	2	2	2	1	3	3	2	2	1
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Risk Event 22					Risk Event 23					Risk Event 24					Risk Event 25					Risk Event 26					Risk Event 27				
Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S
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2	4	4	3	1	2	3	2	3	1	4	5	4	3	1	3	2	3	3	2	1	4	3	4	1	2	2	4	2	1
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1	4	3	3	2	2	3	4	2	2	5	4	5	4	1	3	3	2	3	3	1	3	5	2	2	3	2	2	3	1
2	3	3	2	1	2	4	4	3	2	5	3	4	2	1	1	4	3	4	1	1	2	3	4	2	1	3	4	2	1
3	3	2	4	1	3	2	2	2	1	3	3	5	4	1	3	3	3	4	2	1	3	3	2	2	2	3	2	4	2
3	2	2	2	1	3	3	2	2	1	4	5	5	3	1	2	3	3	2	2	2	2	4	2	1	1	4	4	2	2
2	4	3	2	1	2	4	3	2	1	5	5	5	3	1	1	2	4	3	2	2	2	4	4	2	2	3	2	3	1
3	3	2	3	1	1	3	3	4	1	4	4	5	3	1	1	3	3	4	3	1	4	5	2	2	3	2	2	3	1
2	3	2	2	1	1	3	3	4	1	5	5	4	5	1	1	3	4	4	3	2	4	4	2	2	2	4	2	3	2
3	3	2	3	1	1	4	3	3	1	5	3	5	4	1	1	2	4	4	3	1	4	3	3	2	1	2	2	4	1
2	2	2	3	1	3	4	4	2	1	4	3	3	4	1	3	4	3	4	3	1	4	4	4	3	2	4	2	3	2

Risk Event 28					Risk Event 29					Risk Event 30					Risk Event 31					Risk Event 32					Risk Event 33				
Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S
4	4	4	4	2	2	1	3	2	2	3	3	3	4	1	2	4	3	3	4	2	3	4	4	2	5	3	5	4	1
4	4	3	4	1	1	3	2	3	2	2	4	5	3	2	2	3	2	2	4	3	3	4	3	3	4	3	5	3	2
3	4	4	5	3	1	3	2	3	1	3	4	4	2	2	4	2	3	1	3	2	4	5	4	2	4	2	3	3	2
5	4	4	5	2	3	2	2	2	2	2	5	5	3	2	3	3	2	2	5	3	4	5	4	3	5	3	3	4	1
5	4	4	3	3	2	3	2	2	2	3	4	4	3	2	2	2	4	3	5	2	3	5	2	1	4	4	3	3	1
5	4	4	3	1	3	3	2	2	2	3	3	4	2	1	2	4	4	2	4	4	2	3	3	1	5	2	4	2	1
4	3	5	3	2	2	3	3	2	3	2	3	3	4	1	3	2	3	3	3	2	3	5	2	2	4	4	4	4	1
5	4	5	5	2	1	3	2	3	2	4	3	3	3	1	2	2	3	3	5	2	3	3	4	2	5	3	3	2	1
5	3	4	5	1	1	1	3	2	1	4	3	4	2	2	4	4	3	2	4	2	3	5	2	2	4	2	3	4	2
5	4	5	3	2	3	3	2	2	2	3	4	4	2	2	2	2	3	2	5	2	3	4	3	3	3	2	3	2	1
4	3	3	3	2	2	2	3	2	3	2	3	5	4	1	2	4	3	3	4	4	2	3	3	2	5	4	5	4	1
5	3	4	5	2	2	2	2	2	1	2	5	5	4	2	4	3	2	2	3	2	3	5	2	2	4	3	3	3	2
5	4	5	4	2	1	2	3	2	3	2	4	4	4	3	3	3	2	2	4	4	3	3	2	2	4	4	3	3	1
3	4	4	3	3	1	3	3	3	2	3	4	4	3	1	3	3	2	2	5	3	2	5	2	1	5	3	3	2	1
4	3	5	4	2	2	2	2	2	2	3	3	3	2	2	4	3	2	1	3	2	3	5	3	2	3	3	4	3	2
4	4	4	3	2	1	2	2	3	1	4	3	3	3	3	3	3	2	2	5	3	3	3	3	1	3	3	5	2	1
4	3	4	4	3	3	2	3	2	2	3	4	3	3	2	3	2	4	3	4	3	4	3	3	3	4	4	4	4	1
3	3	4	4	3	1	2	3	3	2	2	5	3	3	2	2	4	2	2	4	2	2	5	3	3	4	3	3	2	1
4	3	4	5	3	3	3	3	1	1	3	3	4	3	2	3	4	3	3	3	3	3	3	2	2	4	4	5	3	1
4	4	4	4	2	2	2	2	2	2	3	4	4	2	2	3	3	2	2	4	2	4	3	3	3	4	3	5	4	2

Risk Event 34					Risk Event 35					Risk Event 36					Risk Event 37					Risk Event 38				
Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S
2	2	2	2	2	1	2	3	3	1	5	3	3	4	1	2	2	2	2	3	3	1	2	2	1
1	1	2	1	1	2	3	4	2	2	4	4	4	4	1	2	2	1	3	2	2	3	3	1	1
2	3	2	1	1	2	4	2	3	1	3	4	4	3	2	1	3	1	3	1	3	2	3	2	1
1	1	2	2	1	1	3	2	2	2	3	5	5	4	1	1	3	3	3	2	3	3	2	3	1
1	2	2	1	1	3	2	3	3	2	5	4	4	4	1	2	2	3	2	2	3	2	2	2	1
1	3	3	1	1	1	3	2	3	1	4	4	4	4	1	1	2	3	3	3	2	2	3	3	1
2	2	2	1	1	1	2	3	2	1	5	4	3	4	1	1	2	2	2	2	2	2	2	2	1
2	2	2	1	2	2	3	3	2	2	5	4	4	4	1	2	1	2	2	3	3	2	1	1	1
1	2	3	1	1	3	3	3	3	1	4	4	4	3	1	2	2	2	3	2	2	1	1	1	1
1	1	2	1	2	1	2	3	3	1	5	3	3	3	1	1	3	2	2	3	4	3	2	2	1
1	2	2	1	1	2	4	4	2	2	5	3	4	4	1	1	3	2	2	2	2	2	3	1	1
1	3	2	2	2	3	4	2	2	2	4	5	3	3	1	1	2	2	2	3	3	3	1	2	1
2	3	3	2	2	2	4	4	3	1	3	4	5	4	1	2	3	2	3	3	3	1	2	2	1
2	3	1	1	2	3	2	2	3	2	4	4	5	4	1	1	3	2	1	3	3	2	2	3	1
2	3	3	1	1	3	2	2	2	1	4	4	4	3	2	1	3	3	2	3	4	1	2	2	1
2	1	2	1	2	2	2	3	2	2	4	4	4	3	1	1	3	3	2	3	2	1	2	1	1
2	3	2	1	2	3	4	4	3	1	4	4	3	3	2	1	2	3	3	2	4	2	2	1	1
2	2	3	2	2	1	4	2	2	2	3	4	3	3	2	1	3	2	1	3	2	2	3	2	1
2	3	2	2	2	2	3	3	2	1	5	5	5	2	2	2	2	3	2	3	2	3	3	2	1
1	1	3	1	1	2	2	4	3	1	5	4	4	2	1	2	1	3	1	2	2	2	1	1	1

Risk Event 39					Risk Event 40					Risk Event 41					Risk Event 42					Risk Event 43					Risk Event 44				
Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S
2	3	3	3	1	4	4	5	3	2	1	4	3	4	4	2	2	4	1	2	2	3	4	4	3	3	5	3	5	2
3	3	3	2	2	5	5	4	4	3	2	2	3	4	2	1	2	3	1	1	3	4	3	2	4	2	5	4	3	1
2	3	2	3	2	4	3	5	5	2	2	2	3	4	3	2	3	4	1	1	2	5	3	2	4	2	4	3	5	2
1	1	2	3	2	4	4	5	5	2	2	3	4	3	3	2	2	2	2	1	2	3	5	2	4	3	4	5	5	2
1	3	3	3	2	3	5	4	4	2	1	2	3	2	3	2	2	3	2	1	2	3	5	2	3	2	5	3	3	2
1	3	1	1	2	5	4	3	4	1	2	3	2	2	2	3	4	2	1	1	3	5	3	4	2	4	5	3	4	1
3	3	3	2	1	4	3	4	5	1	1	3	3	4	3	3	2	2	2	1	2	4	3	2	4	2	5	4	5	2
2	2	2	3	2	4	4	4	4	2	2	2	3	3	3	3	3	2	2	1	2	4	3	3	4	3	4	5	5	2
1	2	1	1	3	4	4	4	4	2	1	4	2	4	4	2	2	3	2	2	3	3	3	4	2	3	4	5	5	2
3	3	3	1	3	5	5	4	4	2	2	4	3	2	4	2	4	2	2	1	3	4	5	3	4	4	3	3	3	2
3	2	2	3	1	3	5	5	4	3	1	3	4	4	2	1	3	3	2	1	2	3	3	3	3	2	5	4	4	2
2	2	2	1	2	4	3	3	3	3	2	4	2	4	3	3	3	4	2	1	3	4	4	4	4	2	4	4	4	1
1	3	1	1	3	3	4	5	4	2	1	3	3	2	2	2	3	4	1	1	4	3	5	2	2	4	5	3	5	2
1	3	3	3	1	5	3	5	4	2	1	2	2	2	4	1	2	3	2	2	3	4	5	4	2	3	5	5	5	1
2	3	2	2	2	4	5	4	3	3	1	4	4	2	3	2	3	3	1	1	3	4	5	4	4	2	3	4	3	2
2	3	3	1	3	4	5	4	3	3	2	3	4	4	4	3	2	3	2	1	3	3	4	3	3	4	3	5	4	2
3	1	3	2	2	4	3	3	5	1	2	4	4	3	2	3	3	4	1	1	3	5	4	2	4	4	4	5	5	2
3	1	1	2	1	3	5	3	5	2	2	2	4	4	3	2	3	3	1	1	3	4	3	3	3	3	4	5	4	1
2	3	2	1	1	4	4	3	5	1	2	3	2	4	4	3	3	3	2	1	2	5	3	4	3	2	4	5	4	2
1	3	1	3	3	5	4	4	4	3	1	3	4	2	3	1	4	4	2	1	1	3	3	3	2	4	3	5	4	2

Risk Event 45					Risk Event 46					Risk Event 47				
Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S
5	4	5	5	2	4	3	3	2	2	4	3	2	1	1
4	3	5	5	2	5	4	4	3	1	3	3	2	2	1
4	4	4	5	3	5	5	5	4	1	2	4	4	2	1
5	4	5	4	2	4	5	4	4	1	3	3	3	3	1
4	3	5	4	3	5	5	3	2	1	2	3	3	2	1
5	5	3	3	2	4	4	4	3	2	2	4	3	3	1
3	3	5	3	2	4	5	4	2	1	2	5	3	2	1
4	5	5	5	4	5	5	3	4	1	2	3	3	1	1
4	4	4	4	2	5	5	4	3	1	2	2	2	2	1
3	3	3	4	3	4	5	4	3	1	3	5	4	1	2
5	5	3	5	4	4	4	3	4	1	3	5	4	1	1
5	5	5	4	2	4	4	5	3	1	2	4	3	1	2
3	4	5	4	3	3	5	3	3	1	4	4	3	2	1
4	4	4	3	4	4	4	3	3	1	2	4	2	2	1
5	5	5	5	2	4	4	3	4	1	2	5	2	3	1
3	3	4	4	3	3	5	4	2	1	3	3	2	1	2
5	5	4	4	4	4	4	5	3	1	2	4	3	3	1
4	5	4	3	2	4	4	4	4	1	3	4	3	1	1
3	5	3	4	3	3	5	5	4	1	2	5	3	1	1
4	5	5	4	2	3	3	4	3	2	3	4	4	3	1

Risk Event 48					Risk Event 49					Risk Event 50				
Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S
3	4	4	3	2	3	5	3	3	1	4	4	4	4	5
1	3	2	4	2	4	5	4	2	1	3	4	5	3	4
3	4	3	3	1	5	4	4	2	1	4	5	4	4	5
1	3	4	2	1	4	4	4	3	1	5	4	5	3	4
2	2	2	3	2	4	4	5	3	1	5	5	4	3	4
2	4	4	4	2	4	4	4	2	1	4	4	4	2	5
3	2	4	4	2	3	5	3	2	1	4	4	4	4	4
1	2	3	3	2	5	3	5	2	1	4	4	5	2	5
2	2	2	2	1	4	4	5	3	1	5	5	5	4	5
1	4	3	2	1	3	3	5	2	1	4	5	5	2	5
3	4	3	2	1	4	5	4	3	1	4	4	4	2	4
3	4	2	4	1	3	5	4	3	1	3	4	4	4	5
2	3	2	3	2	4	5	3	1	1	3	4	5	4	4
3	2	4	3	2	3	4	5	3	1	4	4	5	4	5
2	4	4	2	2	5	4	4	3	2	4	5	4	2	5
2	4	4	2	1	5	3	4	2	2	3	4	5	4	5
3	3	4	4	2	3	5	4	1	2	5	5	4	3	5
2	4	4	2	2	4	4	5	3	1	4	5	4	2	4
3	4	2	3	2	5	5	3	3	2	4	5	4	3	4
3	2	2	2	1	4	3	3	2	2	3	5	5	3	4

Risk Event 51					Risk Event 52					Risk Event 53				
Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S
2	3	5	2	5	1	3	2	1	3	2	2	4	3	4
2	4	5	3	4	2	4	4	2	5	1	4	3	1	3
1	3	5	2	5	1	3	3	3	4	1	3	4	2	2
2	4	4	4	4	1	4	3	1	4	2	3	4	1	3
1	3	5	4	5	1	3	3	2	5	2	4	3	3	4
1	4	4	4	4	1	4	4	1	3	1	4	2	2	2
2	5	5	3	4	2	2	4	3	4	1	2	3	2	3
2	4	4	2	4	1	2	4	2	3	2	2	4	1	4
1	4	5	2	5	1	4	4	1	3	2	2	3	3	4
1	5	4	2	4	1	4	2	2	3	1	3	2	3	3
2	4	5	3	4	2	4	3	3	4	2	2	3	1	2
1	4	5	4	5	2	4	2	2	4	1	4	4	1	3
2	3	5	4	5	2	2	2	2	3	1	2	3	3	2
2	5	4	3	4	2	4	4	3	3	2	3	3	2	3
1	3	5	2	4	2	2	4	3	4	2	4	4	2	3
2	4	5	3	4	2	3	4	2	4	1	3	4	3	4
2	5	4	3	4	1	2	4	2	4	1	4	3	2	3
1	3	4	3	4	2	4	2	3	5	1	3	2	2	3
1	5	4	2	4	2	4	2	2	4	2	3	3	2	3
2	5	5	4	4	2	4	4	2	4	1	4	4	3	2

Risk Event 54					Risk Event 55					Risk Event 56				
Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S
1	2	4	1	5	2	3	3	1	3	2	3	2	1	3
1	4	4	1	3	3	3	3	2	2	1	4	3	1	3
1	4	4	1	3	3	2	4	2	4	2	3	3	1	3
1	2	4	2	5	1	4	3	2	4	1	3	3	1	3
1	4	4	1	3	1	4	4	3	4	2	4	4	2	3
2	3	3	1	5	3	2	2	3	4	1	4	2	2	5
1	4	5	2	4	1	2	5	3	3	1	2	4	1	3
1	3	3	2	3	3	3	3	3	2	2	4	4	1	4
1	3	3	1	3	2	2	4	1	4	1	2	4	1	3
2	4	3	1	5	2	4	2	1	2	2	3	4	1	5
1	2	3	1	4	3	2	4	2	2	1	3	4	1	4
2	3	4	2	4	1	2	3	1	2	2	3	3	2	3
1	2	3	2	3	2	3	3	3	4	1	4	4	2	5
1	4	4	1	3	2	4	4	2	2	1	2	4	1	5
2	2	5	1	4	1	3	3	1	3	1	3	2	1	5
2	3	3	1	4	2	4	4	3	4	1	4	3	1	4
1	2	5	2	5	2	2	5	3	3	1	4	4	2	4
2	4	4	1	3	1	3	3	2	2	2	4	3	1	4
2	3	3	2	3	3	3	3	2	4	2	3	4	1	3
1	4	3	1	3	3	2	3	1	3	1	4	4	1	4

Risk Event 57					Risk Event 58					Risk Event 59					Risk Event 60					Risk Event 61					Risk Event 62				
Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S
4	3	3	2	1	2	2	3	1	1	3	3	4	2	5	1	2	1	1	3	2	1	2	3	1	2	1	3	1	2
3	5	4	3	3	1	2	3	1	1	2	3	2	3	3	1	1	3	1	2	1	2	2	3	1	1	2	2	1	2
5	3	4	1	2	1	2	4	1	1	2	2	3	1	3	2	2	1	2	4	2	2	2	3	1	1	3	2	1	3
4	5	4	2	1	1	3	4	3	1	3	1	4	1	5	1	2	2	2	2	2	2	2	2	1	1	1	2	2	1
5	3	3	3	2	1	3	4	2	1	2	2	2	1	5	1	3	1	2	3	2	1	1	4	1	2	2	3	2	2
4	4	4	2	2	2	3	3	2	2	3	1	3	2	4	1	1	1	1	4	2	1	3	4	1	1	2	3	1	1
3	5	4	1	1	2	2	3	3	1	2	3	4	1	5	1	3	2	1	3	2	2	2	4	2	2	1	1	1	3
5	4	3	2	2	2	2	3	1	2	3	1	2	2	5	1	2	1	1	2	1	2	3	3	2	1	3	1	1	1
4	4	4	1	2	1	4	3	3	1	1	3	3	2	3	2	2	3	1	3	2	1	2	2	1	1	2	1	1	3
4	5	4	1	3	1	3	2	3	2	3	3	2	2	3	2	1	1	1	3	1	2	1	3	2	2	1	1	2	1
3	4	3	2	2	2	3	3	1	1	3	2	4	1	5	2	3	2	2	2	2	2	1	4	2	2	1	3	2	2
4	3	4	3	3	1	3	3	1	1	1	2	4	2	4	1	2	2	1	2	1	2	1	4	2	1	2	1	2	2
4	5	4	3	2	2	4	3	3	2	2	2	2	2	3	2	1	2	1	3	1	1	2	3	1	2	1	1	2	2
4	5	3	3	1	1	4	4	3	1	3	2	3	1	5	2	1	1	1	2	2	2	1	3	2	2	3	1	2	1
5	4	5	2	3	1	3	3	2	2	3	2	2	1	3	2	3	3	1	4	2	2	3	2	2	1	1	2	2	2
3	4	5	3	1	1	2	3	1	1	3	1	2	2	4	1	1	1	1	4	1	1	3	2	1	1	3	3	2	3
4	4	5	1	1	1	2	4	2	1	3	2	3	3	4	1	3	1	2	2	1	2	2	4	1	2	2	2	2	3
5	4	3	1	1	1	3	3	3	2	3	3	3	1	4	2	1	3	1	3	2	1	1	2	2	2	3	1	2	3
5	3	3	2	1	1	2	3	3	1	3	2	3	1	5	2	1	1	2	3	2	3	1	3	1	1	3	3	2	1
4	3	4	1	1	1	4	3	2	2	3	1	2	3	4	1	1	1	2	2	2	2	2	3	1	2	2	2	2	3

Risk Event 63					Risk Event 64					Risk Event 65					Risk Event 66					Risk Event 67					Risk Event 68				
Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S
2	1	3	2	3	2	1	2	2	3	2	2	2	2	2	5	3	3	4	3	4	3	3	2	3	1	3	4	2	5
2	3	1	2	2	3	1	1	1	3	2	3	1	1	4	4	4	4	4	2	2	2	2	2	4	1	2	4	1	5
2	2	2	2	3	4	3	3	2	2	1	2	2	2	2	3	4	4	3	3	2	2	3	1	2	1	2	3	2	3
1	1	2	2	2	3	1	1	1	2	1	3	1	1	3	4	4	3	4	3	3	3	3	2	2	1	4	4	1	5
2	1	2	1	2	2	1	1	2	3	2	1	2	2	2	5	5	3	4	2	3	1	3	1	4	2	4	3	1	4
1	3	1	1	3	3	3	3	1	1	1	3	3	1	3	4	3	2	3	2	2	2	3	2	2	1	3	3	1	5
1	3	1	2	2	4	3	3	1	2	2	2	2	2	2	4	4	3	4	2	3	2	3	2	2	2	3	4	1	5
1	1	3	2	3	2	3	1	1	1	1	1	1	1	2	4	4	4	3	2	2	3	2	1	2	3	2	4	2	5
1	2	2	2	3	2	1	2	1	1	2	3	2	1	3	4	4	2	4	1	4	1	2	2	4	2	4	4	2	5
2	2	2	2	3	3	3	1	1	3	2	2	3	2	3	4	3	3	4	2	2	3	2	2	4	2	2	3	1	3
2	1	2	1	4	2	2	2	1	1	1	2	3	2	2	3	5	3	3	2	3	3	3	1	4	2	3	3	1	4
1	1	2	1	2	2	2	2	2	2	1	3	2	1	4	4	4	4	4	2	2	1	2	1	3	3	2	4	2	5
2	1	3	1	3	2	2	2	1	3	2	1	3	1	3	3	3	2	3	1	3	1	4	1	2	2	3	3	1	4
1	3	2	1	4	4	2	2	1	1	2	1	2	2	3	5	3	3	4	3	4	1	3	2	2	1	4	4	1	4
1	1	2	1	2	2	2	3	2	3	1	2	2	2	2	5	4	3	4	1	3	3	2	1	3	1	3	3	2	4
1	1	2	1	4	4	2	3	2	2	1	2	3	1	3	4	4	3	4	2	3	2	2	1	2	2	2	3	2	5
1	2	1	1	3	2	3	1	1	2	2	2	3	1	3	3	4	4	4	1	2	3	4	1	4	3	3	4	1	3
2	1	3	2	3	2	1	2	1	1	2	1	3	2	3	4	4	4	3	2	4	1	3	1	4	2	3	4	1	3
1	3	3	2	4	4	2	3	1	3	2	1	3	1	3	5	5	3	5	2	4	2	3	1	4	1	4	4	1	4
2	2	2	1	2	4	1	3	1	2	1	1	3	1	2	4	4	3	3	1	2	2	2	1	3	3	4	3	1	4

Risk Event 69					Risk Event 70					Risk Event 71					Risk Event 72					Risk Event 73					Risk Event 74				
Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S
1	2	4	1	3	4	2	3	5	2	1	2	2	2	3	1	4	4	3	5	2	2	2	2	4	3	1	2	2	3
3	3	4	2	2	4	2	4	5	2	2	2	2	1	2	1	5	4	3	3	1	1	1	1	2	2	1	3	1	4
2	1	3	1	4	3	4	3	4	2	1	2	1	2	2	2	5	5	2	5	1	2	3	1	4	3	1	2	1	2
1	3	2	2	2	5	4	4	4	2	2	1	1	2	3	2	5	4	3	3	1	3	2	1	4	1	3	2	1	4
3	2	2	1	4	4	4	3	5	2	2	2	3	2	3	2	5	5	4	5	3	3	3	2	2	1	2	1	2	2
1	2	4	2	3	5	3	4	3	2	1	2	2	2	3	3	4	3	3	4	2	3	1	1	4	1	3	3	2	3
1	1	4	2	2	4	4	4	4	2	2	2	2	1	3	2	3	3	3	5	2	3	2	2	4	2	2	3	1	3
3	2	2	2	2	3	3	4	5	1	1	2	1	2	2	2	3	4	2	3	2	2	2	1	3	3	1	1	2	4
1	1	4	2	4	3	3	3	5	1	1	2	2	1	3	3	3	4	3	3	3	2	2	1	3	2	2	2	1	2
2	2	2	1	4	3	4	3	4	3	2	1	3	2	3	2	3	3	4	4	3	2	3	1	3	2	1	1	2	3
2	3	3	2	3	4	3	2	4	3	1	1	2	2	1	2	3	4	2	4	2	1	1	2	3	3	3	1	2	4
2	1	4	2	4	5	3	2	5	1	1	2	2	2	3	1	5	3	4	3	2	1	2	2	2	1	3	2	1	2
3	1	2	1	4	3	4	3	3	1	2	2	3	1	3	3	4	3	4	5	3	1	1	2	2	1	3	3	2	4
2	2	3	1	2	4	4	4	4	3	1	2	2	1	2	2	4	4	3	3	3	2	3	2	2	1	2	3	1	3
1	3	3	1	4	4	2	4	4	1	1	1	2	2	2	1	4	3	2	5	1	2	2	2	2	3	1	1	2	3
3	1	4	1	3	5	2	4	4	1	2	1	1	2	3	2	4	5	2	5	3	3	1	2	4	3	1	1	2	2
2	3	4	1	4	5	4	4	3	2	2	1	3	1	3	1	5	3	4	5	2	3	1	2	3	3	2	3	2	3
3	3	3	1	3	4	4	2	4	3	2	1	1	1	3	1	3	4	2	4	1	2	2	2	3	1	3	1	2	2
3	1	2	1	3	5	4	4	4	3	2	2	3	2	1	1	5	4	4	4	2	3	3	2	3	3	1	3	2	3
1	2	4	1	3	5	3	4	5	2	2	2	2	2	2	2	5	5	4	4	3	3	2	2	4	1	1	3	2	2

Risk Event 75					Risk Event 76					Risk Event 77					Risk Event 78					Risk Event 79					Risk Event 80				
Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S
2	2	3	3	2	2	3	2	4	4	3	3	4	2	1	2	2	2	1	2	1	3	3	1	5	3	2	3	2	1
4	2	2	2	2	2	4	2	3	4	4	3	2	2	1	3	1	1	2	1	2	2	3	2	3	2	3	3	1	1
2	3	3	4	2	3	3	4	2	3	4	3	2	4	2	3	1	2	2	1	3	4	3	1	3	3	2	1	2	3
4	2	2	2	1	2	3	2	3	2	3	2	2	3	1	3	1	2	2	2	1	4	5	1	4	2	2	2	2	2
4	2	2	2	1	3	2	3	4	2	4	3	3	3	2	3	2	1	2	2	1	3	4	1	5	4	3	1	2	1
4	3	2	3	1	1	4	4	4	4	3	2	3	4	1	3	2	2	1	3	1	4	4	2	5	4	1	1	1	2
2	2	3	4	1	2	3	4	2	2	5	1	2	3	2	2	1	1	2	2	2	3	3	1	5	3	1	3	2	2
3	2	2	3	1	2	2	4	3	3	4	2	3	3	2	1	1	1	1	2	3	3	3	2	4	3	2	3	1	3
4	2	2	2	2	3	2	3	4	4	4	3	3	3	2	3	1	1	1	2	1	2	4	2	5	4	3	1	2	3
2	2	2	4	1	3	3	4	3	2	3	3	3	3	3	3	2	1	2	3	2	4	4	1	5	3	2	1	2	1
2	3	3	4	1	3	2	3	2	4	3	3	3	4	1	1	1	1	2	2	2	2	5	2	4	2	2	3	1	3
2	3	3	3	2	3	3	4	3	3	5	2	2	3	1	1	1	2	1	3	3	2	4	2	3	2	3	2	1	2
4	2	3	2	2	3	2	3	3	3	3	2	3	3	2	1	1	1	2	1	2	3	3	1	3	2	1	3	1	1
3	2	3	2	2	3	2	3	4	3	5	3	2	3	2	3	1	2	1	1	1	2	5	2	4	3	2	3	1	3
3	3	2	3	2	1	4	3	4	3	3	2	4	4	1	1	1	2	2	2	2	3	4	1	3	2	2	1	1	1
2	3	2	4	2	2	4	2	4	3	5	2	3	2	2	2	2	1	2	3	2	3	3	1	3	2	3	2	1	3
2	3	2	3	2	2	3	4	3	4	4	2	3	3	1	3	1	1	1	1	1	2	4	1	4	4	1	2	1	1
3	3	2	2	1	1	4	4	4	3	5	2	2	2	1	1	1	1	2	3	2	4	5	1	5	3	3	1	1	2
2	2	3	3	2	1	4	3	4	2	3	1	3	3	2	1	2	1	2	2	2	4	5	2	4	4	2	2	2	2
2	3	2	4	1	3	2	2	4	2	5	1	3	2	2	2	1	2	1	1	1	4	3	2	4	2	3	1	1	1

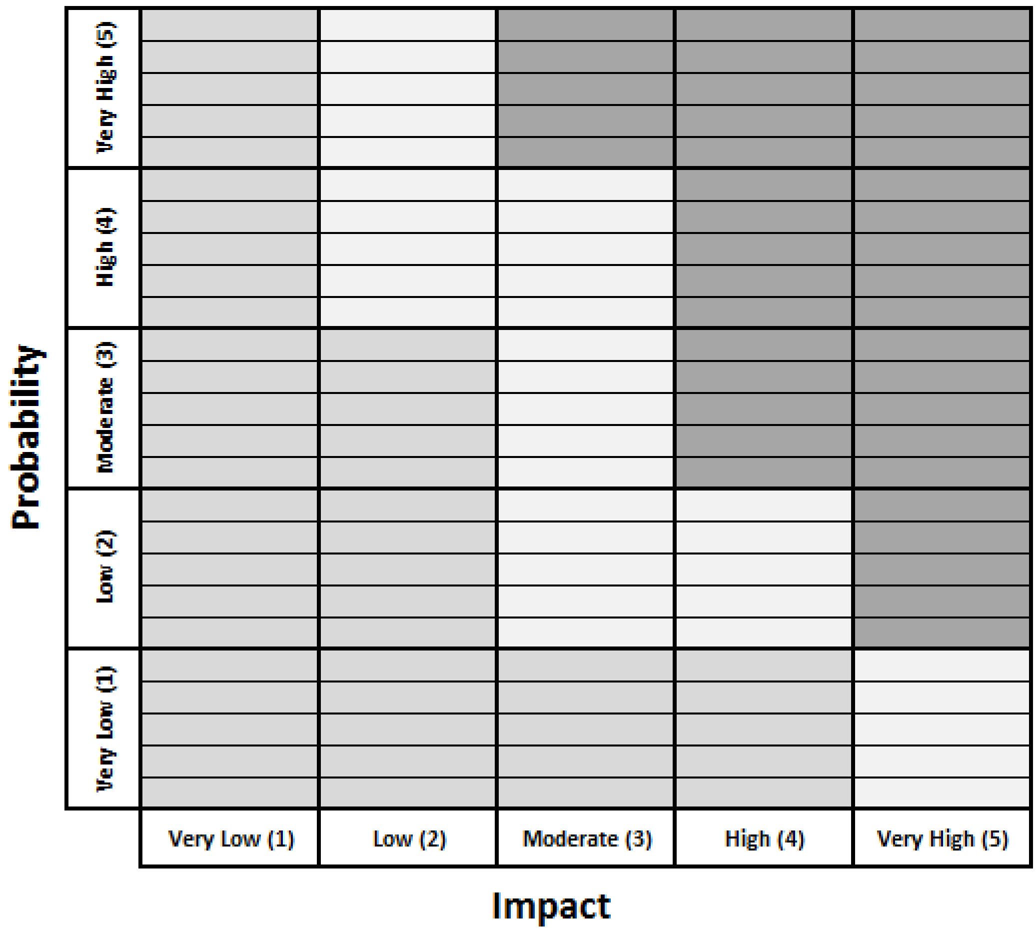
Risk Event 81					Risk Event 82					Risk Event 83					Risk Event 84					Risk Event 85					Risk Event 86				
Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S
2	2	4	1	3	4	5	4	3	3	3	5	5	3	5	2	2	4	2	3	2	1	3	2	3	2	4	2	3	4
2	1	3	1	3	4	5	5	2	5	3	4	5	4	4	2	3	2	3	3	2	2	2	1	4	1	3	3	1	3
2	2	4	1	3	4	5	4	3	3	3	5	4	5	4	1	3	2	1	4	3	1	2	1	2	2	3	4	2	2
1	1	3	1	3	3	4	3	2	5	4	5	5	4	4	2	2	3	2	5	4	1	3	2	2	1	2	2	3	4
2	1	4	1	3	4	4	3	4	5	4	3	4	5	4	1	3	3	3	3	2	2	4	2	3	1	2	4	3	3
2	2	2	2	3	5	5	4	3	5	3	4	5	5	5	1	2	4	1	5	4	1	2	2	3	1	3	4	3	3
2	3	3	1	4	5	5	3	3	5	4	4	3	5	3	2	2	2	1	3	4	1	4	1	2	2	2	2	3	4
1	1	2	1	3	3	5	3	3	5	2	4	4	4	3	2	4	3	2	4	3	1	3	1	2	2	4	4	2	4
1	3	3	2	3	3	3	5	2	4	4	5	3	5	5	2	3	2	1	4	4	1	2	2	2	1	4	3	2	4
2	2	4	1	3	5	3	5	2	4	4	5	4	3	3	2	2	3	1	3	2	2	2	2	2	1	4	3	2	4
2	1	4	1	4	4	3	5	3	3	4	4	3	5	4	2	2	2	1	3	4	3	4	2	3	1	3	4	1	4
1	2	2	2	3	3	4	5	2	4	3	3	3	4	5	1	2	2	3	3	4	3	3	2	4	2	4	3	2	4
1	1	3	1	4	4	4	3	4	5	3	5	5	4	4	2	2	4	3	3	2	3	3	2	2	2	3	3	1	3
1	3	3	1	3	3	5	4	2	4	2	4	5	4	4	2	4	4	3	4	4	1	4	1	2	1	3	2	1	3
1	2	3	2	4	4	5	3	2	3	2	5	3	5	4	2	2	2	1	5	2	1	4	2	2	2	3	4	2	3
2	3	4	2	3	3	4	5	3	5	3	3	5	5	3	1	4	2	2	4	4	1	3	2	3	2	2	4	2	4
2	1	2	1	4	5	5	5	2	4	3	5	5	4	5	2	4	2	1	3	2	3	4	2	2	2	2	2	2	3
2	1	3	2	2	4	3	3	2	4	2	4	5	5	5	1	3	4	2	4	4	1	4	2	4	1	2	4	2	4
1	1	3	1	3	3	4	3	3	4	4	5	4	4	5	1	2	3	1	4	4	1	3	1	2	1	4	2	3	4
2	2	4	2	3	3	3	5	4	5	4	3	4	3	5	2	3	3	3	4	4	3	3	1	3	1	3	3	1	4

Risk Event 87					Risk Event 88					Risk Event 89					Risk Event 90					Risk Event 91					Risk Event 92				
Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S
3	1	2	1	2	1	3	3	1	2	1	4	4	1	4	1	4	5	1	5	3	3	3	1	2	3	3	4	2	1
2	1	2	1	4	2	3	2	1	4	2	2	4	1	5	3	2	4	2	3	2	1	3	2	3	2	3	3	3	1
1	1	2	1	3	2	3	2	2	4	1	4	5	1	4	3	4	4	2	3	3	2	2	1	2	1	2	4	4	2
1	3	4	1	2	1	3	4	2	2	1	2	4	1	5	2	4	3	3	4	2	1	3	2	3	2	4	4	2	2
1	3	4	1	3	2	2	2	2	4	1	3	5	1	5	2	4	3	1	4	1	1	2	2	2	2	3	4	3	2
3	1	3	1	3	1	2	4	2	2	3	3	4	1	5	1	2	4	1	5	1	2	2	2	3	3	3	3	2	1
3	1	4	1	4	2	4	4	2	4	2	3	5	1	4	2	4	5	1	4	1	1	2	1	4	2	3	4	3	2
1	1	2	1	3	2	3	2	1	3	2	2	4	1	5	2	2	3	1	3	1	2	1	2	3	2	2	4	4	1
3	1	3	1	3	2	4	2	2	2	2	2	5	1	4	1	3	3	1	5	2	3	2	3	4	2	3	4	4	2
2	1	4	2	2	1	4	3	2	4	2	2	5	1	5	2	3	3	2	4	3	1	2	3	2	2	2	2	4	3
3	1	3	2	2	1	4	2	2	3	1	2	5	2	5	2	4	4	2	4	3	3	1	1	3	2	4	4	3	3
3	2	4	1	3	1	2	3	2	2	2	2	4	1	4	3	2	4	2	4	1	1	2	2	4	2	4	4	2	3
1	3	3	1	3	1	3	2	1	3	2	4	4	1	4	3	2	4	2	4	3	3	1	2	3	3	3	3	3	1
2	3	3	1	4	2	2	4	2	3	3	3	4	1	5	1	3	4	1	5	1	2	2	1	3	3	3	2	3	2
2	3	4	1	3	1	2	3	2	3	1	2	5	1	4	3	4	3	1	3	2	2	2	1	2	3	3	3	2	1
1	2	2	1	3	2	2	4	2	3	2	4	5	1	4	1	3	3	1	5	1	2	1	1	3	3	2	3	4	2
2	1	4	2	3	1	2	4	1	2	2	2	4	1	5	2	3	3	1	4	1	2	1	2	2	2	4	4	3	2
2	1	4	1	2	2	4	3	1	2	2	2	4	1	5	3	3	4	1	4	2	1	3	1	3	2	4	3	4	2
3	3	2	1	3	2	3	2	2	2	2	2	5	1	5	1	2	5	2	5	2	1	2	1	2	2	4	3	4	1
1	3	2	1	4	2	2	4	2	3	2	4	4	1	4	1	4	4	1	5	2	1	2	2	3	3	4	2	4	2

Risk Event 93					Risk Event 94					Risk Event 95					Risk Event 96					Risk Event 97					Risk Event 98				
Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S	Probability	Time	Cost	Quality	H&S
3	4	5	5	2	1	1	3	2	2	5	4	3	2	2	2	4	5	3	4	2	3	2	3	2	5	3	5	4	2
5	4	4	4	2	1	1	1	1	1	5	5	3	2	2	2	5	5	5	5	4	2	3	2	2	3	2	3	4	3
5	3	4	5	2	1	1	3	1	1	5	3	4	4	2	2	5	5	3	4	2	3	4	3	2	4	3	5	3	2
4	4	3	3	2	2	1	1	2	1	4	3	5	4	3	1	5	4	4	4	4	4	4	1	2	3	4	4	4	2
3	3	4	3	2	2	1	2	2	1	5	4	4	2	1	2	3	4	4	5	4	2	3	1	1	4	4	5	3	1
3	4	4	4	1	2	2	3	2	2	5	5	4	4	2	2	4	3	4	4	4	3	2	2	2	3	3	4	4	3
3	4	3	4	2	1	2	2	1	3	4	5	4	4	3	2	4	3	3	5	4	2	3	2	1	5	3	4	3	2
4	3	3	3	2	1	2	3	1	2	4	3	5	2	2	1	5	5	5	4	3	2	2	2	2	3	5	4	4	3
4	4	5	4	1	1	2	2	1	3	4	3	4	3	3	2	5	3	4	4	2	3	2	3	1	5	4	5	3	1
3	3	4	4	1	2	1	3	2	2	4	5	3	4	2	1	4	5	5	5	3	2	3	2	2	4	3	4	3	2
4	4	4	4	2	2	1	1	2	1	5	4	4	2	2	1	3	3	3	4	3	4	4	2	1	4	4	4	4	2
5	4	5	5	2	2	2	1	2	3	4	5	4	3	3	1	3	3	4	4	3	2	3	2	1	4	5	5	3	2
4	5	4	4	2	2	2	1	1	3	5	3	3	4	2	2	3	5	5	5	2	4	4	3	2	3	4	3	4	3
5	4	4	3	1	1	1	3	1	1	5	3	3	3	2	1	3	3	4	4	3	2	4	1	1	3	4	3	4	1
3	4	5	5	2	2	2	2	2	2	4	3	5	4	2	1	4	4	4	5	4	4	3	2	2	5	3	4	4	2
4	3	2	4	1	2	2	2	2	3	5	4	5	3	2	2	4	3	4	5	3	4	4	2	2	3	4	5	3	3
4	4	3	3	1	1	2	2	1	1	5	3	4	3	3	2	5	3	5	4	2	4	4	3	2	5	3	5	3	2
3	3	5	5	2	1	2	3	1	3	5	5	3	4	3	2	5	3	5	5	3	3	2	3	1	4	4	3	4	2
5	4	3	4	2	1	1	2	1	3	5	3	4	3	2	1	5	5	5	4	3	4	4	3	1	4	2	5	3	2
4	4	3	4	1	1	1	2	1	3	5	5	5	2	1	1	5	4	3	4	3	2	2	3	2	4	3	4	4	2

Risk Event 98					Risk Event 99					Risk Event 100					Risk Event 101					Risk Event 102					Risk Event 103					Risk Event 104					Risk Event 105				
Probabilit	Time	Cost	Quality	H&S	Probabilit	Time	Cost	Quality	H&S	Probabilit	Time	Cost	Quality	H&S	Probabilit	Time	Cost	Quality	H&S	Probabilit	Time	Cost	Quality	H&S	Probabilit	Time	Cost	Quality	H&S	Probabilit	Time	Cost	Quality	H&S	Probabilit	Time	Cost	Quality	H&S
5	3	5	4	2	3	4	4	3	2	2	1	3	2	2	2	2	3	3	3	4	5	4	4	2	3	1	1	1	1	2	4	2	3	1	2	4	2	1	1
3	2	3	4	3	2	3	5	2	1	1	2	2	1	2	3	3	2	3	1	5	3	4	5	1	3	3	2	2	1	2	3	2	2	2	3	3	2	2	1
4	3	5	3	2	3	4	4	2	2	2	2	3	3	2	2	2	3	2	3	4	4	5	4	2	2	3	2	3	1	1	3	4	4	3	2	4	4	1	1
3	4	4	4	2	4	4	4	2	2	1	2	4	3	1	2	3	2	3	3	3	5	4	5	1	1	3	2	3	1	3	3	2	4	1	3	4	4	1	1
4	4	5	3	1	3	5	5	2	2	1	3	3	3	2	4	2	3	2	1	5	4	3	4	1	2	3	3	2	2	1	3	3	4	3	4	3	4	2	1
3	3	4	4	3	3	2	5	1	1	1	2	2	2	1	4	2	3	2	2	5	4	3	4	2	1	2	1	1	1	1	3	2	4	2	2	3	2	1	1
5	3	4	3	2	4	4	3	3	2	2	3	3	1	1	2	3	3	3	3	4	3	4	3	2	3	3	1	2	2	3	3	4	2	1	3	4	4	1	1
3	5	4	4	3	2	3	3	3	2	2	2	2	3	1	2	3	4	2	1	5	4	4	4	2	2	2	1	2	1	2	4	2	4	2	2	5	4	1	1
5	4	5	3	1	3	4	5	3	2	2	3	2	2	1	4	2	2	2	1	4	4	5	4	2	1	3	1	3	1	2	2	4	3	2	4	3	2	1	1
4	3	4	3	2	3	4	4	2	2	1	3	3	3	2	2	2	4	3	2	5	3	3	5	2	3	1	1	2	1	2	4	2	4	1	4	3	2	1	1
4	4	4	4	2	2	4	3	3	1	2	2	3	1	2	2	3	2	4	3	4	5	5	5	3	2	1	1	2	1	3	3	4	2	1	2	4	2	1	1
4	5	5	3	2	3	3	5	2	2	1	2	4	1	1	2	1	4	4	3	5	4	4	4	3	2	3	3	3	2	1	4	4	3	3	4	3	2	2	1
3	4	3	4	3	3	5	5	1	1	1	3	3	3	2	4	2	2	2	2	4	3	3	4	2	1	3	3	3	2	1	2	2	3	2	2	4	4	1	1
3	4	3	4	1	3	4	4	2	1	2	2	4	1	1	4	3	2	2	1	4	4	4	5	3	1	1	1	1	1	3	2	3	4	2	2	4	2	2	1
5	3	4	4	2	4	3	4	3	2	1	1	4	3	1	4	3	3	3	1	3	4	4	5	1	3	1	3	2	1	2	4	3	2	1	2	5	2	1	1
3	4	5	3	3	3	4	3	2	1	2	1	2	3	2	3	3	3	3	2	4	4	3	5	2	1	1	1	2	1	2	2	2	3	2	2	3	3	1	1
5	3	5	3	2	4	3	3	1	1	1	1	3	3	2	2	3	4	3	1	4	4	3	4	2	1	2	3	3	1	2	4	4	4	3	3	4	2	1	1
4	4	3	4	2	3	5	5	3	1	1	3	3	2	2	4	2	2	2	2	5	3	5	5	3	1	3	2	3	1	1	4	2	4	3	3	3	3	1	1
4	2	5	3	2	3	4	3	1	1	2	3	3	2	2	3	2	4	1	1	4	4	3	5	2	1	3	1	2	1	3	4	3	2	2	3	3	3	1	1
4	3	4	4	2	4	4	4	3	2	1	1	3	2	1	2	3	3	2	3	4	4	4	4	2	3	2	1	2	1	1	4	2	2	3	2	4	2	1	1

Appendix H: Sample of Matrix Table



Appendix I: Checklist Reliability (SPSS, Cronbach's Alpha)

```
RELIABILITY
  /VARIABLES=RE1 RE2 RE3 RE4 RE5 RE6 RE7 RE8 RE9 RE10 RE11 RE12 RE13
RE14 RE15 RE16 RE17 RE18 RE19 RE20 RE21
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /STATISTICS=DESCRIPTIVE
  /SUMMARY=MEANS.
```

Reliability

Notes

Output Created		25-May-2014 04:54:32
Comments		
Input	Data	E:\Thesis\Payam Rasooli-probability.sav
	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	20
	Matrix Input	
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the procedure.
Syntax		RELIABILITY /VARIABLES=RE1 RE2 RE3 RE4 RE5 RE6 RE7 RE8 RE9 RE10 RE11 RE12 RE13 RE14 RE15 RE16 RE17 RE18 RE19 RE20 RE21 /SCALE('ALL VARIABLES') ALL /MODEL=ALPHA /STATISTICS=DESCRIPTIVE /SUMMARY=MEANS.
Resources	Processor Time	00 00:00:00.016
	Elapsed Time	00 00:00:00.010

[DataSet1] E:\Thesis\Payam Rasooli-probability.sav

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	20	100.0
	Excluded[a]	0	.0
	Total	20	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.861	.866	21

Item Statistics

	Mean	Std. Deviation	N
F1	1.9500	.75915	20
F2	1.9500	.94451	20
F3	2.3000	.73270	20
F4	2.9500	.75915	20
F5	2.8500	.87509	20
F6	3.3000	.80131	20
C1	3.2000	.83351	20
C2	4.1000	.85224	20
C3	3.0500	.68633	20
C4	4.2000	.69585	20
C5	2.9500	.88704	20
D1	3.8500	.67082	20
D2	3.1000	.71818	20
D3	4.4000	.50262	20
D4	4.3000	.73270	20
D5	2.6000	.82078	20
D6	1.4500	.51042	20
D7	4.1000	.96791	20
D8	2.4000	.59824	20
D9	3.1000	.78807	20
D10	2.7500	.71635	20

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	3.088	1.450	4.400	2.950	3.034	.696	21

```
RELIABILITY
  /VARIABLES=RE1 RE2 RE3 RE4 RE5 RE6 RE7 RE8 RE9 RE10 RE11 RE12 RE13
RE14 RE15 RE16 RE17 RE18 RE19 RE20 RE21
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /STATISTICS=DESCRIPTIVE
  /SUMMARY=MEANS.
```

Reliability

Notes

Output Created		25-May-2014 05:03:25
Comments		
Input	Data	E:\Thesis\Payam Rasooli-Time impact.sav
	Active Dataset	DataSet2
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	20
	Matrix Input	
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the procedure.
Syntax		RELIABILITY /VARIABLES=RE1 RE2 RE3 RE4 RE5 RE6 RE7 RE8 RE9 RE10 RE11 RE12 RE13 RE14 RE15 RE16 RE17 RE18 RE19 RE20 RE21 /SCALE('ALL VARIABLES') ALL /MODEL=ALPHA /STATISTICS=DESCRIPTIVE /SUMMARY=MEANS.
Resources	Processor Time	00 00:00:00.000
	Elapsed Time	00 00:00:00.004

```
[DataSet2] E:\Thesis\Payam Rasooli-Time impact.sav
```

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	20	100.0
	Excluded[a]	0	.0
	Total	20	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha[a]	Cronbach's Alpha Based on Standardized Items[a]	N of Items
.818	.816	21

Item Statistics

	Mean	Std. Deviation	N
F1	2.7500	.78640	20
F2	2.9000	.85224	20
F3	4.1500	.81273	20
F4	2.1000	.55251	20
F5	3.9000	.71818	20
F6	2.7000	.65695	20
C1	3.9000	.91191	20
C2	2.9000	.85224	20
C3	2.6500	.74516	20
C4	3.4500	.60481	20
C5	2.3500	.58714	20
D1	3.9000	.71818	20
D2	2.9000	.85224	20
D3	4.5000	.51299	20
D4	3.9500	.68633	20
D5	2.9500	.88704	20
D6	2.9500	.82558	20
D7	3.9500	.82558	20
D8	2.9500	.75915	20
D9	2.8500	.81273	20
D10	3.0500	.68633	20

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	3.224	2.100	4.500	2.400	2.143	.426	21

```
RELIABILITY
  /VARIABLES=RE1 RE2 RE3 RE4 RE5 RE6 RE7 RE8 RE9 RE10 RE11 RE12 RE13
RE14 RE15 RE16 RE17 RE18 RE19 RE20 RE21
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /STATISTICS=DESCRIPTIVE
  /SUMMARY=MEANS.
```

Reliability

Notes

Output Created		25-May-2014 05:08:05
Comments		
Input	Data	E:\Thesis\Payam Rasooli-Cost Impact.sav
	Active Dataset	DataSet3
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	20
	Matrix Input	
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the procedure.
Syntax		RELIABILITY /VARIABLES=RE1 RE2 RE3 RE4 RE5 RE6 RE7 RE8 RE9 RE10 RE11 RE12 RE13 RE14 RE15 RE16 RE17 RE18 RE19 RE20 RE21 /SCALE('ALL VARIABLES') ALL /MODEL=ALPHA /STATISTICS=DESCRIPTIVE /SUMMARY=MEANS.
Resources	Processor Time	00 00:00:00.000
	Elapsed Time	00 00:00:00.007

```
[DataSet3] E:\Thesis\Payam Rasooli-Cost Impact.sav
```

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	20	100.0
	Excluded[a]	0	.0
	Total	20	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha[a]	Cronbach's Alpha Based on Standardized Items[a]	N of Items
.819	.815	21

Item Statistics

	Mean	Std. Deviation	N
F1	2.6500	.58714	20
F2	1.5000	.60698	20
F3	2.6500	.67082	20
F4	3.1000	.64072	20
F5	3.8500	.87509	20
F6	3.1000	.78807	20
C1	3.0000	.72548	20
C2	3.7500	.78640	20
C3	2.8000	.69585	20
C4	4.4500	.75915	20
C5	2.3500	.48936	20
D1	3.7000	.47016	20
D2	2.4500	.60481	20
D3	4.2000	.69585	20
D4	3.9000	.91191	20
D5	2.9500	.94451	20
D6	3.0500	.82558	20
D7	4.1000	.78807	20
D8	2.9000	.71818	20
D9	2.9000	.78807	20
D10	2.1000	.78807	20

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	3.117	1.500	4.450	2.950	2.967	.558	21

```
RELIABILITY
  /VARIABLES=RE1 RE2 RE3 RE4 RE5 RE6 RE7 RE8 RE9 RE10 RE11 RE12 RE13
RE14 RE15 RE16 RE17 RE18 RE19 RE20 RE21
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /STATISTICS=DESCRIPTIVE
  /SUMMARY=MEANS.
```

Reliability

Notes

Output Created		25-May-2014 05:11:33
Comments		
Input	Data	E:\Thesis\Payam Rasooli-Quality Impact.sav
	Active Dataset	DataSet4
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	20
	Matrix Input	
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the procedure.
Syntax		RELIABILITY /VARIABLES=RE1 RE2 RE3 RE4 RE5 RE6 RE7 RE8 RE9 RE10 RE11 RE12 RE13 RE14 RE15 RE16 RE17 RE18 RE19 RE20 RE21 /SCALE('ALL VARIABLES') ALL /MODEL=ALPHA /STATISTICS=DESCRIPTIVE /SUMMARY=MEANS.
Resources	Processor Time	00 00:00:00.000
	Elapsed Time	00 00:00:00.006

```
[DataSet4] E:\Thesis\Payam Rasooli-Quality Impact.sav
```

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	20	100.0
	Excluded[a]	0	.0
	Total	20	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.841	.837	21

Item Statistics

	Mean	Std. Deviation	N
F1	2.8500	.58714	20
F2	1.3500	.48936	20
F3	2.4000	.68056	20
F4	1.7500	.78640	20
F5	2.3500	.74516	20
F6	1.6000	.50262	20
C1	1.2000	.41039	20
C2	2.8500	.74516	20
C3	2.6500	.67082	20
C4	3.3000	.86450	20
C5	1.8500	.74516	20
D1	3.4000	.68056	20
D2	2.5500	.60481	20
D3	4.1500	.81273	20
D4	4.0500	.75915	20
D5	2.8500	.74516	20
D6	2.9500	.82558	20
D7	4.0500	.88704	20
D8	2.2500	.71635	20
D9	2.9500	.82558	20
D10	1.2500	.44426	20

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	2.600	1.200	4.150	2.950	3.458	.802	21

```
RELIABILITY
  /VARIABLES=RE1 RE2 RE3 RE4 RE5 RE6 RE7 RE8 RE9 RE10 RE11 RE12 RE13
RE14 RE15 RE16 RE17 RE18 RE19 RE20 RE21
  /SCALE('ALL VARIABLES') ALL
  /MODEL=ALPHA
  /STATISTICS=DESCRIPTIVE
  /SUMMARY=MEANS.
```

Reliability

Notes

Output Created		25-May-2014 05:15:06
Comments		
Input	Data	E:\Thesis\Payam Rasooli-Health and Safety Impact.sav
	Active Dataset	DataSet5
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	20
	Matrix Input	
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the procedure.
Syntax		RELIABILITY /VARIABLES=RE1 RE2 RE3 RE4 RE5 RE6 RE7 RE8 RE9 RE10 RE11 RE12 RE13 RE14 RE15 RE16 RE17 RE18 RE19 RE20 RE21 /SCALE('ALL VARIABLES') ALL /MODEL=ALPHA /STATISTICS=DESCRIPTIVE /SUMMARY=MEANS.
Resources	Processor Time	00 00:00:00.000
	Elapsed Time	00 00:00:00.006

```
[DataSet5] E:\Thesis\Payam Rasooli-Health and Safety Impact.sav
```

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	20	100.0
	Excluded[a]	0	.0
	Total	20	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha[a]	Cronbach's Alpha Based on Standardized Items[a]	N of Items
.887	.883	21

Item Statistics

	Mean	Std. Deviation	N
F1	3.2500	.78640	20
F2	1.6500	.58714	20
F3	1.4000	.50262	20
F4	1.4000	.50262	20
F5	1.2000	.41039	20
F6	1.2000	.41039	20
C1	1.2000	.41039	20
C2	1.1000	.30779	20
C3	1.4000	.50262	20
C4	1.1500	.36635	20
C5	1.2000	.41039	20
D1	1.1000	.30779	20
D2	1.1500	.36635	20
D3	1.3000	.47016	20
D4	1.1000	.30779	20
D5	1.7500	.71635	20
D6	1.1500	.36635	20
D7	1.4000	.50262	20
D8	1.2000	.41039	20
D9	1.1000	.30779	20
D10	1.1000	.30779	20

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	1.397	1.100	3.250	2.150	2.955	.264	21