A GENERIC RISK AND VULNERABILITY ASSESSMENT FRAMEWORK FOR INTERNATIONAL CONSTRUCTION PROJECTS

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ABSTRACT

A GENERIC RISK AND VULNERABILITY ASSESSMENT FRAMEWORK FOR INTERNATIONAL CONSTRUCTION PROJECTS

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Project Risk Management (PRM) comprises of identification and assessment, analysis and mitigation of risk factors in order to meet the project objectives. Risk identification and assessment process has the greatest importance as the risk models are constructed based on previously defined risk sources and their interrelations. Although previous studies have concentrated on the relation between risk events and their consequences, the link between them must be modeled by considering the various chains of risk events and the capacity of a "system" to react to risk events simultaneously. The concept of "risk paths" should be used to identify chains of risk events by means of a Hierarchical Risk Breakdown Structure (HRBS) rather than defining individual risk factors. The "system" consists of the characteristics of the project, company and involved parties. The word "vulnerability" is used to describe the degree to which a project is susceptible to adverse effects of change. The aim of the current study is to develop a common vocabulary and design a HRBS that integrates vulnerability factors with risk factors. A generic risk and vulnerability assessment framework for international construction projects is presented in this research. The justification of the factors considered within the breakdown structure has been achieved by referring to real construction projects carried out by Turkish contractors in international markets.

Keywords: Project Risk Management, International Construction, Vulnerability

ÖZ

ULUSLARARASI İNŞAAT PROJELERİ İÇİN GELİŞTİRİLEN
GENEL BİR RİSK VE RİSK KIRILGANLIĞI DEĞERLENDİRME ÇALIŞMASI

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Proje Risk Yönetimi (PRY) proje amaçlarını karşılamak için risk faktörlerinin tanımlanması ve değerlendirilmesi, analizi ve hafifletilmesinden oluşmaktadır. Risk modelleri daha önce tanımlanmış olan risk kaynakları ve onların ilişkileri üzerine kurulduğu için, risklerin tanımlanması ve değerlendirilmesi işlemi büyük önem taşımaktadır. Önceki çalışmalar risk olayları ve sonuçları arasındaki ilişki üzerine yoğunlaşmış olmalarına karşın; bunların aralarındaki bağlantı, risk olaylarının zincirleme ilişkileri ve "sistemin" risk olaylarına karşı reaksiyon verme kapasitesi eş zamanlı olarak düşünülerek modellenmelidir. "Risk yolları" kavramı, risk faktörlerini ayrı ayrı belirlemek yerine, Hiyerarşik Risk Ayrıştırma Yapısı (HRAY) bazında, risk olay zincirlerini tanımlamak için kullanılmalıdır. "Sistem" proje, ülke ve ilgili partilerin karakterlerinden oluşmaktadır. "Risk kırılganlığı" kelimesi bir projenin olumsuz koşullara olan hassasiyet derecesini tanımlamak için kullanılmaktadır. Bu çalışmanın amacı, risk kırılganlığı faktörlerini risk faktörleri ile birleştiren ortak bir dil geliştirmek ve buna uygun bir HRAY tasarlamaktır. Bu araştırmada, uluslararası inşaat projeleri için genel bir risk ve risk kırılganlığı değerlendirme yapısı sunulmaktadır. HRAY içinde düşünülen faktörlerin doğrulanması, Türk müteahhitler tarafından uluslararası pazarlarda gerçekleştirilen gerçek inşaat projeleri referans alınarak başarılmıştır.

Anahtar kelimeler: Proje Risk Yönetimi, Uluslararası İnşaat, Risk Kırılganlığı

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To

My Family

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LIST OF ABBREVIATIONS

PRM	Project Risk Management
HRBS	Hierarchical Risk-Breakdown Structure
SE	Source-Event
KM	Knowledge Management
MCDM	Multi Criteria Decision Making
SMART	Simple Multi Attribute Rating Technique
AHP	Analytical Hierarchy Process
CII	The Construction Industry Institute
RS	Risk Sources
R1	Risk Sources-1
R2	Risk Sources-2
RE	Risk Events
RC	Risk Consequences
V1	Vulnerability-1
V2	Vulnerability-2
V3	Vulnerability-3
RV	Risk-Vulnerability
JV	Joint Venture
PDS	Project Delivery System

CHAPTER 1

INTRODUCTION

1.1. Research Objectives

Project Risk Management (PRM) is a combined process of identifying and assessing, analyzing and mitigating risks so that the project objectives are met. Risk identification deserves extensive research as other processes can only be carried out based on the pre-defined risks. Meanwhile, risk assessment has some bottlenecks in quantitative applications. The available studies about risk identification and assessment tend to focus on only the risk source and consequence relationship while ignoring the source-event interaction and the influence of the "system" (that consists of project characteristics, company factors and involved parties). This research intends to overcome this shortcoming in PRM by:

- introducing a model combining two main concepts: "risk paths" and "vulnerability",
- identifying the major risk and vulnerability parameters and explore the interrelations between them, and
- developing a common vocabulary and design a Hierarchical Risk-Breakdown Structures (HRBS) that integrates vulnerability factors with risk factors.

1.2. Research Background

Various definitions for "risk paths" and "vulnerability" can be found in the previous studies. Firstly, "risk paths" can be described as the figurative representation of the correlation occurring between risk causes and effects through a risk network (Dikmen et. al., 2008). It is common in the literature to classify risks according to their sources by creating HRBS. In practice, there are cause-effect relationships between the risk factors leading to a network form rather than a one-way hierarchical structure. Although the phrase "risk path" was not pronounced, the concept of setting the relationships between risk sources, events and consequences had been worked on by several researchers. Dikmen et al. (2007) stated the importance of the connection between risk sources and consequences. In DoD (Department of Defense) (2006), a future root cause, a probability, and the consequence of risks decided to be linked together. Tah and Carr (2000) created cause-and-effect diagrams to identify the links between risk sources and the consequences. Similarly, Han et al. (2007) presented the cause-effect" diagram which was a symbolic picture of HRBS in which the possible causes of risks and their interactions with other profit/loss factors were identified and arranged by branch and arrow symbols.

By considering the importance of mutual relations between risk factors, Han et al. (2008) proposed the concept of "risk path" that showed the causal relationships between risk sources and events. They suggested a "SE" (Source-Event) checklist of risk sources and related events. They argue that risk identification should entail identification of risk paths rather than individual sources of risk. In this research, the concept of risk paths is accepted to have a vital role in clarifying and interrelating risk sources to their consequences that pass through risk events.

Secondly, "vulnerability" is described as the characteristics of a system that will create the possibility for harm (Ezell, 2007; Sarewitz et al., 2003). Dikmen et al. (2007) names a system's properties as "controllability/manageability" while Zhang (2007) calls them as "project vulnerability" which stands for the extent or the capacity of a system to respond or cope with a risk event. No matter how it is called, the features of the "system" including an organization's capability to manage risks, the company factors as well as the project characteristics should be taken into account during risk identification and assessment.

It is believed that a complete PRM can not be achieved without a successful risk identification and assessment process that integrates risk paths and vulnerability parameters. Although several researchers (Han et al., 2008, Dikmen et al., 2007, Zhang, 2007) mentioned their importance, none of them tried to unite both risk paths and vulnerabilities in a single model. As a combined approach is needed to obtain adequate and applicable results during assessment, "a generic risk and vulnerability assessment framework" will be proposed for international construction projects in this research.

1.3. Research Methodology

The research for the generic risk and vulnerability assessment framework was conducted in four main steps as:

- Literature Review
- Preliminary Risk and Vulnerability (RV) Assessment Framework
- Case Studies
- Final Risk and Vulnerability (RV) Assessment Structure

Definitions which were mentioned before as risk, PRM, risk path, and vulnerability were acquired at the beginning of literature review. Then, each step of PRM was studied in detail. For risk identification and assessment phase researches about HRBS and risk paths were usually encountered in the previous works. Although this thesis is mainly based on this part, risk analysis and mitigation techniques were investigated in order to make a reliable and practical assessment model. In the second part of the research, a preliminary RV assessment framework was created. For this purpose risk paths and vulnerabilities are defined and entered to the first model. As this model was only created by the data from literature and judgment, it had to be verified. The verification was achieved in the third step by collecting information about real case studies. Then considering the outcomes of cases, the first model was modified and the final risk and vulnerability (RV) assessment structure was obtained. For the assessment of the final framework prediction models were generated and as a result of this study the RV assessment questionnaire was prepared to perform data collection in the forthcoming studies.

1.4. Research Organization

In Chapter 2 of this study, information gathered from a detailed literature review about PRM and the shortcomings of the previous risk assessment procedures derived from literature are presented. In Chapter 3, basic definitions about risk paths and vulnerability are summarized and the preliminary risk and vulnerability assessment framework is discussed. In Chapter 4, the preliminary assessment framework is tested by five real case studies and lessons learned from these cases are highlighted. The required modifications of the preliminary model are summarized and the final risk and vulnerability assessment structure is proposed in Chapter 5. Details of a questionnaire designed to collect relevant data for risk assessment are explained and recommendations for the risk and vulnerability analysis are also depicted in this chapter. Conclusions derived from the study are discussed in Chapter 6. In addition to the main text, this study also includes an appendix, in which a sample of the risk and vulnerability questionnaire can be found.

CHAPTER 2

LITERATURE REVIEW

2.1. Definition of Risk

Projects which are located in a different country than their owner and/or contractor are called international projects. International projects are subject to risks more than domestic projects, as they comprise much more types of issues and unknowns caused from working in an uncommon environment (Walewski and Gibson, 2003). In order to cope with the challenges of the global area, the definition of risk for international construction projects must be clarified. A variety of definitions of risk and corresponding researchers are shown in Table 1.

Table 1: Definitions of Risk

Study	Definition
Al-Bahar (1990)	"the exposure to the chance of occurrences of events adversely or favorably affecting project objectives as a consequence of uncertainty."
Cano and Cruz (2002)	"an uncertain event that, if it occurs, has a positive (opportunities) or negative (threats) effect on a project objective."
DoD (2006)	"a measure of future uncertainties in achieving program performance goals and objectives within defined cost, schedule and performance constraints."
Hillson (2002)	"an umbrella term, with two varieties: _ ''opportunity'' which is a risk with positive effects; _ ''threat'' which is a risk with negative effects."
ISO/IEC Guide 73 (2002)	"combination of the probability of an event and its consequence."
PMBOK (2000)	"an uncertain event or condition that, if occurs, has a positive or negative effect on a project objective."
RAMP (1998)	"the presence of potential or actual treats or opportunities that influence the objectives of a project during construction, commissioning, or at time of use."
Raz et al. (2002)	"undesired events that may cause delays, excessive spending, unsatisfactory project results, safety or environmental hazards, and even total failure."
U.S. DoE (2003)	"a measure of the potential inability to achieve overall project objectives within defined cost, schedule, and technical constraints."

After harmonizing the definitions mentioned in Table 1, in this research, risk is described as "a cause of change or uncertainty that has effects on project success in a positive or negative manner".

2.2. Project Risk Management (PRM)

Project Risk Management (PRM) is described as a system to identify risks and reduce their negative effects on the project by creating various risk occurrence scenarios and developing risk response strategies (Dikmen et. al., 2008). The PMI PMBoK (2000) explains it as ''the systematic process of identifying, analyzing, and responding to project risk". Research in construction and PRM began in the 1960s (Edwards and Bowen 1998) and the definition is not unique to construction industry.

According to Hertz and Thomas (1984), PRM provides a comprehensive understanding and consciousness of the risks associated with the successful completion of the project objectives or project success criteria. Flanagan and Norman (1993) define it as an organized process involving identification, assessment, and mitigation of the impact of risk. In addition, they have the idea that PRM is a discipline for living with the likelihood that future events may cause adverse effects, which disregards the possibility of opportunities. Chapman and Ward (1997) state aim of PRM as removing or reducing the possibility of underperformance. Similarly, PMBoK (2004) considers PRM as "increasing the probability and impact of positive events, and decreasing the probability and impact of events adverse to the project." It is also thought to involve "coordinated activities to direct and control an organization with regard to risk" (ISO/IEC Guide 73, 2002).

Another explicit definition is done by Dikmen et al. (2004) which describes PRM as definition of objective functions to represent the expected outcomes of a project, measuring the probability of achieving objectives by generating different risk occurrence scenarios to ensure meeting/exceeding the preset objectives. Likewise, Jaafari (2001) regards PRM to be a representation involving project variables and project's objective functions side by side.

PRM is a continuous development that takes place throughout the life cycle of an organization. The methodology identifies and measures the unknowns, develops and implements the appropriate mitigation options and tracks the implementation to ensure successful risk reduction (DoD, 2006). Turnbaugh (2005) states that the three major processes of PRM include risk identification, risk quantification, and risk response development and control. This is similar to an earlier approach developed by Perry and Haynes (1985), which includes the processes of risk identification, analysis, and response. Gray and Larson (2005) believe that PRM includes the process of risk identification, analysis, and handling.

In the last two decades, many researchers developed formal risk management processes and methodologies to control project risks and improve project performance (Edwards and Bowen 1998, Flanagan and Norman 1993). Hampton (1993) designed a six step PRM process which includes: set objectives, identify risks, evaluate risks, design a comprehensive program, implement the program, and monitor results. In a similar manner, Rad (2003) categorized risk documentation and communication as risk planning, identification, assessment and analysis, handling/action planning, and tracking and control. In U.S., DoE (Department of Energy) (2003), the process was regarded to plan for risk, assess (identify and analyze) risk areas, develop risk-handling options, monitor, and document the risks.

Identification and analysis of project risks are required for effective risk management. One of the most important steps in PRM is the identification of the various risks. After identification of these risks, the focus changes to the risk analysis and assessment, and then to selection of mitigation methods that will minimize, transfer, avoid, and control the risks (Godfrey 1996).

When construction risk management literature is examined, it is observed that RM studies can be grouped under four categories (Dikmen et. al, 2004).

1. Development of conceptual frameworks and process model for systematic RM,
2. Investigation of risks, risk management trends and perceptions,

3. Application of risk identification and analysis techniques in specific projects, and
4. Development of risk management support tools.

The model proposed in this research can be categorized in the first group as a conceptual framework will be generated for risk assessment. Considering the aforementioned researches, PRM has three below given tasks;

1. risk identification,
2. risk analysis, and
3. risk mitigation

In this study, the focus is basically on the first step, risk identification in which risk paths are created and vulnerability parameters are integrated into them to generate a risk-vulnerability framework. Then, possible risk analysis techniques will be explained and a risk assessment process will be proposed. In the following parts of this chapter, literature survey on the three steps of PRM will be explained in detail.

2.2.1. Risk Identification

Some of researchers similar to Chapman (2001) stated that risk identification should be considered as a part of risk analysis process. However in this study, risk identification is handled as a separate part in PRM, actually a preceding activity of risk analysis rather than its part, considering its importance and effects on the results of risk analysis.

Risk identification is the first step of PRM where potential risks, risk sources, and their consequences are recognized and examined (Mo Nui Ng, 2006). It is a process of systematically and continuously identifying, categorizing, and assessing the significance of risks associated with a project. It has significant importance as risk analysis and response generation is performed based on the pre-defined risks (Al-Bahar and Crandall, 1990). Risk identification enables being sure about the limits of project objectives and that the capability of the contractor and the owner laid within these project limits. Further, this step can provide base for choosing the suitable organizational structure, tendering method, contract strategy, and finally the allocation of risks among the project participants (McKim, 1990).

Risk classification attempts to structure the various risks that may affect a project (Perry and Hayes 1985, Cooper and Chapman 1987, Tah et al. 1993, Wirba et al. 1996). In construction projects, several researchers have conducted studies to identify and categorize construction risk factors (Ashley et al. 1987, Al-Bahar and Crandall 1990, Kangari 1995, Smith and Bohn 1999). According to Al-Tabtabai and Diekmann (1992), the primary basis for identification of risks is historical data, experience and intuition. The most known method for risk identification is risk checklists. Toakley and Ling (1991) stated that risk checklists which are simple catalogues to prevent risk being overlooked, have been compiled by many construction firms. Similar to Al-Tabtabai and Diekmann (1992), Akintoye and Macleod (1997) declared that based on the intuitions, experience and judgments, almost all the project managers know and use risk checklists as a PRM technique. Other than risk checklists, various methods like semi-structured interviews and working group techniques such as brainstorming technique, nominal group technique and Delphi technique are used for identification of project risks.

Typical risk identification techniques are summarized by Boehm (1991) as checklists, examination of decision drivers, comparison with experience (assumption analysis), and decomposition. In addition to these techniques, generic risk breakdown structures are proposed in order to facilitate and formalize the risk identification process. Using these tools, decision-makers may assess the magnitude of different sources of risk and identify potential risk events that may affect project outcomes.

In this study, risks are identified and classified through risk paths. First, a Hierarchical Risk-Breakdown Structure (HRBS) is used to group risk sources. Then, risk sources are linked to risk events and consequences considering vulnerability parameters. In order to lay the background of this categorization, literature review on HRBS, risk paths and vulnerability will be explained in the following sections.

2.2.1.1. Previous Work on the Hierarchical Risk-Breakdown Structures (HRBS)

One common method for defining the most frequent and severe risk factors is to classify them according to their sources and to use a hierarchical structure (Saaty 1980). According to Al-Bahar and Crandall (1990), there are two reasons for creating a taxonomy or classification of risks: 1) to instruct the contractor about the risks, 2) to determine the appropriate risk mitigation techniques concerning their properties. On the other hand, Hillson (2003) states that in order to cope with large amount of data in the best manner, it must be organized properly, and this organization process is achieved by constructing Hierarchical Risk-Breakdown Structures (HRBS) in PRM. HRBS has been defined as "A source-oriented grouping of risks that organises and defines the total risk exposure of the project or business. Each descending level represents an increasingly detailed definition of sources of risk" Hillson (2002b).

A number of authors have described risks specific to international construction (Ashley and Bonner 1987; Sloan and Weisberg 1997; Jaselskis and Talukhaba 1998; Hastak and Shaked 2000; Han and Diekmann 2001; Levitt et al. 2004). When literature is investigated, it is clear that there are numerous risk checklists and risk breakdown structures proposed by different researchers.

Perry (1986) described sixteen sources of risk, five of which relate to construction and three to finance issues. Wideman (1986) generated a risk breakdown structure that has five categories: external-unpredictable, external-predictable but uncertain, internal (non-technical), technical and legal. Ahmad (1990) organized bid/no-bid factors into four main categories—job, firm, market, and resources and proposed an additive multiattribute hierarchy for determining the desirability of a project. Al-Bahar and Crandall (1990) proposed a classification scheme including six risk categories such as acts of god, physical, financial and economic, political and environmental, design and construction-related. McKim (1990) grouped common construction risks as generally uncontrollable and controllable. Flanagan and Norman (1993) classified risk sources as a hierarchy of four layers: the environment, the market or industry, the company and the project. Raftery (1994) defined three separate categories of risk such as risks internal to the project, risks external to the project, and risks regarding the client/the project/project team and project documentation. British Standard 6079 (1996) considered that risks or adverse events generally fall into one of the following five categories: technological, political, managerial, sociological and financial. Conroy and Soltan (1998) referred to four categories of risk, namely human failings, organizational failings, design group failings and design process failings. Leung et al. (1998) categorized risks as internal and external. Bing et al. (1999) identified the risk factors related to international construction joint ventures (JVs) and grouped them into three: internal, project-specific, and external. With ICRAM-1, Hastak and Shaked (2000) determined and analyzed risks in macro, market and project levels. Chapman (2001) arranged risks in environment, industry, client, and project groups. Han and Diekmann (2001) proposed a structure to classify international construction risks in five categories such as political, economic, cultural/legal, technical/construction, and others. Dikmen and Birgonul (2006) placed risks into project and country categories. Dikmen et al. (2007) underlines the need for HRBS in risk identification phase and creates one to categorize risk sources in three levels: risk type, risk category and risk source.

After its construction, a HRBS can create a basis for a risk assessment framework and there are several risk assessment frameworks proposed in the literature. For instance, the HRBS proposed by Tah et al. (1993) was used by Tah and Carr (2000) with small changes to generate a risk quantification methodology. They pinpointed the importance of a common vocabulary for risk and developed a risk information model that facilitates construction of risk databases to be used during risk identification and information retrieval in forthcoming projects. Similarly, Cano and Cruz (2002) presented an integrated methodology called PUMA (Project Uncertainty Management) based on a flexible and generic PRM including HRBS.

The HRBS allows the division of project risks into groups allowing much more organized data collection and assessment strategies. It is certain that HRBS is a vital step in PRM. However, risk assessment can not be realised properly unless various factors such as interrelations among risk groups and factors of vulnerability are considered. Therefore, in this thesis, risk paths are identified rather than individual and disjointed risk factors.

2.2.1.2. The Concept of Risk Paths

Risk paths can be defined as the figurative representation of the correlation occurring between risk causes and effects through a risk network (Dikmen et. al., 2008). The final part of the network is connected to risk consequences which show the overall impact of risks on the project. Although the phrase "risk path" was not pronounced, the concept of setting the relationships between risk sources, events and consequences had been worked on by several researchers.

Dikmen et al. (2007) stated that while creating a risk model, the connection between sources and consequences must be maintained by defining sources, events and consequences in an appropriate manner. DoD (2006) clarified risks to include a future root cause, a probability, and the consequence; and they should be linked together. Tah and Carr (2000) evaluated the interactions between risk factors, risks, and their consequences in cause-and-effect diagrams to identify the links between risk sources and the consequences. Tah and Carr (2001) represented that an accurately defined HRBS enabled the defined risks to be better grouped for the determination of cause-effect relationships. The "cause-effect" diagram was proposed by Han et al. (2007). It was a symbolic picture of HRBS in which the possible causes of risks and their interactions with other profit/lost factors were identified and arranged by branch and arrow symbols. Even before these studies, Al-Bahar and Crandall (1990) pointed out the importance of generating risk events/consequence scenarios representing all reasonable possibilities concerned with the risk sources.

In a similar manner, the concept of "risk path" was proposed by Han et al. (2008) who tried to show the causal relationships between risk sources and events. They suggested a "SE" (Source-Event) checklist to sort risk sources and their related events. Han et al. (2008) argued that risk identification should entail identification of risk paths rather than individual sources of risk. They stated that in order to understand the correlation between risks and their related factors, following a risk path from its source to event was a very beneficial step in risk identification.

In this research, the concept of risk paths is accepted to have a vital role in clarifying and interrelating risk sources to their consequences by passing through risk events. It is obvious that the definition should be enlarged and verified by a contrastive study of the model with practices such as interviews, Delphi technique, panel sessions, brainstorming, etc (Cano and Cruz, 2002).

2.2.2. Risk Analysis Techniques and Their Shortcomings

Risk analysis includes the quantitative evaluation of risk impacts and their probability of occurrence (Mo Nui Ng, 2006). Grose (1990) stated the importance of numerical assessment of risk. Boehm (1991) explained the duty of risk analysis to assess the loss probability and magnitude for identified and integrated risks in risk-item interactions. According to Rao et al. (1994), risk analysis involves the integration of information from numerous sources through quantitative and/or qualitative modeling, while preserving the uncertainty and the complex relationships between the elements of information. U.S. DoE (2003) defined risk analysis in the content of risk rating and prioritization in which risk events were factors of their probability of occurrence, severity of consequence/impact, and relationship to other risk areas or processes. In DoD (2006), risk analysis was summarized to answer the question "How big is the risk?" by using Risk Reporting Matrix.

Many risks can be quantified by measuring their impacts on the project objectives. A variety of techniques have been proposed and used in the construction industry with different success outcomes (McKim, 1990). These include performance models, cost models, network analysis, statistical decision analysis, and quality-factor (like reliability, availability, and security) analysis (Boehm, 1991).

Traditional risk assessment for construction has been synonymous with probabilistic analysis (Liftson 1982, Al-Bahar 1990). Such approaches required events to be mutually exclusive, exhaustive, and conditionally independent. However, construction involves many variables, and it was often difficult to determine causality, dependence and correlations. As a result, subjective analytical methods that rely on historical information and the experiences of individuals and companies have been used to assess the impact of construction risk and uncertainty by Bajaj, Oluwoye, and Lenard (1997). Ibbs and Crandall (1982) developed a risk decision model based on utility theory. Mak and Picken (2000) proposed a methodology to investigate risks to clients, persons or organizations investing in the construction of built facilities. Risk in project cost has been treated using analytical, simulation and decision-tree enumeration (Diekmann 1983, Newton 1992, Touran 1993, Ranisinghe 1994).

In this thesis, risk analysis techniques have been studied in five groups:

1) Sensitivity Analysis
2) Probabilistic Analysis
3) Decision Analysis
4) Multi Criteria Decision Making Techniques
5) Fuzzy Sets

After summarizing the basics of these techniques, the most appropriate one for the risk-vulnerability framework study will be suggested to be used in the forthcoming studies.

Sensitivity analysis is the simplest form of risk analysis. It investigates the effect of change of a single variable and analysis this effect on the whole project. Although it can be handled for any risk element, generally variables having the largest impacts on project cost, schedule, and quantity are preferred (McKim, 1990). If several variables are changed, critical variables are illustrated by graphical representation called spider diagram. McKim (1990) stated one major weakness of sensitivity analysis as the treating of variables separately. This limits the change of many variables at the same time and ignores their dependency. Moreover, sensitivity analysis does not deal with the probability of the occurrence of any event and the user becomes limited to "what-if" questions.

Several authors used sensitivity analysis as a risk analysis tool. For example, Raftery (1994) applied sensitivity analysis on a rehabilitation and redevelopment project in London. Although sensitivity analysis is usually used as a simple technique for risk analysis, a study is conducted by Porter (1981) demonstrates how major project risks can be identified by sensitivity analysis.

As sensitivity analysis is inadequate for evaluation and assessment of risk combinations in a project, probabilistic analysis is proposed in order to overcome the limitations of sensitivity analysis. Being a more complicated risk analysis technique, probabilistic analysis assesses probabilities for each risk by assigning probability distribution functions and then considers changes in the risks in combination (McKim, 1990). The result of the analysis is a range of outcomes over which the final outcome lies. As the most common probability analysis technique, Monte Carlo (MC) simulation can be widely seen in the literature. It is based on experimentation and simulation, and used in situations where a solution in the form of an equation would be difficult or impossible. It is a form of stochastic simulation and requires a set of random numbers to be generated for use in testing various options. The calculation is repeated a number of times which depends on degree of confidence required, to obtain the probability distribution of the project outcome.

One of the earliest efforts regarding the application of probabilistic techniques was carried out by Poliquen (1970). Poliquen applied MC simulation for risk assessment of a port project in Somalia; researched the effectiveness of MC as risk management tool and attracted the attention to difficulties in detection of correlations. Beeston (1986) carried out a research in which it is recommended to use MC simulation as an analytical tool by pointing out the shortcomings and difficulties of MC simulation implementation. Furthermore, the researchers like Dressler (1974), Crandall (1976) and Bennett and Ormerod (1984) declared the pitfalls of deterministic approaches and agreed that the use of MC simulation facilitates risk quantification effectively.

On the other hand, decision analysis is mainly concerned with the process of making decisions (Flanagan and Norman, 1993). It is both an approach to decision making and a set of techniques to guide decisions like long-term, strategic or short-term decisions under risky and uncertain conditions. Algorithms, means-end chain, decision matrix, decision trees and stochastic decision tree analysis are the examples for decision analysis to be applied to PRM process.

According to Akintoye and Macleod (1997), decision tree analysis is one of the most known after sensitivity analysis by contractors and project managers in United Kingdom. This is probably because decision tree analysis allows user to trace the consequences of both present and future courses of actions (McKim, 1990).

There are also Multi Criteria Decision Making (MCDM) Techniques like Simple Multi Attribute Rating Technique (SMART) and Analytical Hierarchy Process (AHP) for risk quantification. Sometimes, Utility theory is utilized with MCDM methods so that overall utility can be calculated by considering objectives and risk factors. As Flanagan and Norman (1993) stated the major objective of MCDM using utility theory is to obtain overall utility function which yields a utility index or measure of worth for a given set of alternatives. Ahmad and Minkarah (1988) applied utility theory to construction bidding to acquire a markup for a competitive bidding environment. Similar to Ahmad and Minkarah, Dozzi et al. (1996) developed a utility theory model for bid markup decisions. McKim (1990) explained utility theory to differ from other methods by taking into account the individual or organizational behavior in a risky situation. He conducted a study including utility theory and accepted that the reaction of different parties could be different under the same risky conditions and the reaction of the same party could be different if the conditions concerning risk were changed.

Based on the SMART philosophy, risk rating by multiplying the probability with severity/impact of each identified risk factors and adding them up to find an overall risk score was utilized by many researchers. Jannadi and Almishari (2003) developed a risk assessor to determine value of risk associated with a particular activity by using risk rating technique. Baccarini and Archer (2001) described the use of risk ranking methodology which aims to rank and prioritize risks in projects. Similarly, Abourizk and Er (2004) applied risk rating technique for the implementation of a structured risk analysis process.

AHP, which was developed by Saaty (1980), is a widely used risk assessment tool. It enables experts to make decisions related with many factors including planning, setting priorities, selecting best among the alternatives and allocating resources. AHP is conducted in three steps such as, performing pair-wise comparison, assessing consistency of pair-wise judgments and computing relative weights. Several researchers conducted studies related with implementation of AHP to construction projects. Russel (1991) analyzed contractor failure in US. Hastak and Shaked (2000) carried out a study regarding international construction risk assessment by using AHP technique. Cheung and Suen (2002) applied AHP for dispute resolution strategy. Dikmen and Birgönül (2006) conducted a study pertinent to risk and opportunity modeling for assessment of international construction projects by using AHP technique.

It can be concluded that the experience and knowledge of construction project participants are vital issues for assessment of level of uncertainty. Therefore, the opinion obtained from experts with many years of experience in construction projects serve as the major input for risk analysis when historical data is not sufficient or unavailable. However, it is not an easy task to quantify the experience and knowledge of experts for risk assessment. Fuzzy set theory (Zadeh, 1965) is the only mathematical tool that can process linguistic terms usually associated experience and knowledge. Thus, there have been a number of attempts to exploit fuzzy logic within the construction risk management domain. Kangari (1988) proposed an integrated knowledge-based system for construction risk management which performs risk analysis by using fuzzy sets before and during the construction phases. Kangari and Riggs (1989) developed a model to test risk assessment using linguistic variables by identifying the problems and benefits of linguistic variables. Eldukair (1990) made a research and developed a method as fuzzy bidding decision method assuming that the experts are capable of measuring a factor on a scale. Chun and Ahn (1992) conducted a research by using fuzzy event trees to quantify the imprecision and judgmental uncertainties of accident progression event trees. Peak et al. (1993) and Lin and Chen (2004) proposed the use of fuzzy sets for the assessment of bidding prices for construction projects. Ross and Donald (1996) used fuzzy fault trees and event trees in risk assessment problems. Wirba et al. (1996) proposed a method in which the likelihood of a risk event occurring, the level of dependence between risks and severity of risk event, are quantified using fuzzy linguistic approach. Tah and Carr (2001) proposed a knowledge-based construction project risk management methodology including a generic process model underlying information model, common language for describing risks and remedial actions by implementation of fuzzy knowledge representation model to conduct quantitative risk analysis. Fuzzy approach is applied to identify relationships between risk sources and the consequences for project performance. Choi et al. (2004) developed a fuzzy-based uncertainty model for risk assessment of underground construction projects.

Under the light of the aforementioned research about five different risk analysis categories and keeping in mind their basic features, in this research, a multi-criteria assessment procedure with subjective judgments (fuzzy risk assessment) is proposed where the relations between different levels of the HRBS are recommended to be revealed by artificial intelligence (AI) techniques such as neural networks, case-based reasoning, details of which will be explained in Chapter 5.

2.2.3. Risk Mitigation

Risk mitigation is described as the step of PRM which intends to reduce, transfer, avoid or control the impact, severity, and probability of occurrence of risk (Mo Nui Ng, 2006). Norris et al. (2000) describes some mitigation methods including percentage sharing of overruns, awarding time but no money, limiting the types of costs that can be recovered, setting liquidated damages rates lower than justifiable, and using liability caps. The sharing of risk gives both parties incentive to avoid and mitigate the threat of cost overrun, therefore minimizing the total cost of risk on a project (Diekmann et al. 1988).

AI-Bahar and Crandall (1990) note that risk management and implementation of risk mitigation methods should be monitored and reviewed for future alternative risk management methods development. The Construction Industry Institute (CII) established several studies which focus on risk control methods such as risk avoidance, risk reduction, risk sharing, risk transfer, insurance, and risk acceptance by establishment of contingency accounts, risk acceptance without any contingency and risk containment (CII 1993).

2.3. Shortcomings of Previous Risk Assessment Procedures

The previous risk assessment procedures and risk breakdown systems have a potential to help decision-makers in creating risk checklists, however, they have two major shortcomings:

1) The risk source-event relation is not usually considered in HRBS. In practice, there are cause-effect relationships between the risk factors leading to a network form rather than a one-way hierarchical structure. Han et al. (2008) discuss the significance of those interrelations and state the diversity and complexity of international risks. They state the limitations of the traditional PRM styles and emphasized on the importance of management of probable risk factors and continuous interaction between different decision-making processes. They propose "risk paths" that show the causal relationships between risk sources and events. They argue that risk identification should entail identification of risk paths rather than individual sources of risk.

2) Risk modeling comprises of formulation of a performance model and quantification of risk impacts on performance by using some risk analysis techniques. Although the integration and practicality of risk analysis techniques are important, they entirely depend on the results of the risk identification phase. During the identification phase, a critical issue, which is defined as "controllability/manageability" by Dikmen et al. (2007) and "project vulnerability" by Zhang (2007) should be considered to construct reliable risk models. Vulnerability

assessment is used to define the characteristics of a system that will create the possibility for harm (Ezell, 2007; Sarewitz et al., 2003). Therefore, the determination of vulnerabilities and managing them is important for increasing the capability to deal with risks.

In this thesis, a generic structure that contains vulnerability and risk factors as well as their cause-effect relations is proposed to eliminate the above stated shortcomings.

CHAPTER 3

THE GENERIC RISK AND VULNERABILITY ASSESSMENT FRAMEWORK

3.1. Development of the Risk-Vulnerability Structure

The risk and vulnerability model constructed in this research is based on a variety of risk factors and vulnerability parameters. A framework involving the interrelations between these two subjects can only be generated by defining several concepts explicitly. Therefore in this chapter, the concept of risk and vulnerability paths will be explained and a generic structure will be proposed.

3.1.1. Definitions

Risk path, as defined by Han et al. (2008), is the combination of risk variables and their cause-and-effect scenarios which made up "tree structures of risk courses". In other words, risk path arranges risk sources and their related events.

Risk source is defined as "item or activity having a potential for a consequence" in ISO/IEC Guide 73 (2002). In AS/NZS 4360 (2004), it is "A source of risk or hazard – the thing which has the intrinsic potential to harm or assist e.g. a dangerous chemical, competitors, government."

Risk event is described by ISO/IEC Guide 73 (2002) and AS/NZS 4360 (2004) as “Occurrence of a particular set of circumstances.” In AS/NZS 4360 (2004), the occurrence of event/incident is used to provide the connection between the risk source and the estimated impact.

Risk impact/consequence is the outcome of an event (ISO/IEC Guide 73, 2002; AS/NZS 4360, 2004). In DoD (2006), it is explained to be “The outcome of a future occurrence expressed qualitatively or quantitatively, being a loss, injury, disadvantage or gain.” PMBoK (2000) expands the risk impact/consequence definition to be “the effect of project objectives if the risk event occurs”. Vulnerability was described by various researchers in the literature (Table 2). NSTAC (1997) argued that vulnerable systems are systems that are exposed and accessible and therefore susceptible to natural hazards.

Table-2: Definitions of Vulnerability

Study	Definition
Agarwal and Blockley (2007)	“A particular form of hazard- a hazard which is internal to the system.”
Blaikie et al. (1994)	"A characteristic of a person or group in terms of their capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard."
Buchanan (1991)	“The scale and complexity of the problems facing the project manager, the degree of uncertainty and risk involved, and to the anticipated degree of contention and resistance which the change is likely to generate.”
Buckle et al. (2001)	“A measure of the exposure of a person to a hazard and indicates the type and severity of the damage that is possible.”
Dictionary.com (2008)	"Susceptibility to injury or attack."
Emergency Management Australia (1998)	"The degree of susceptibility and resilience of the community and environment to hazards."

Table-2: Definitions of Vulnerability (cont'd)

Study	Definition
National Security Telecommunications Advisory Committee (NSTAC) (1997)	"A function of access and exposure."
Nicholls et al. (1999)	"The likelihood of occurrence and impacts of weather and climate related events."
Operationally Critical Threat, Asset and Vulnerability Evaluation (OCTAVE) 2.0 (1999)	"A weakness in an information system, system security practices and procedures, administrative controls, internal controls, implementation, or physical layout that could be exploited by a threat to gain unauthorized access to information or disrupt processing."
Öksüz (2003)	"Vulnerability assessment is for the prediction and identification of the seismic performance and safety level of the building, which might be exposed to severe damage during an expected earthquake."
Winslow (1998) cited in Levine (2004)	"Vulnerable populations are the "social groups who experience limited resources and consequent high relative risk of morbidity and premature mortality."

A system's vulnerability represents the extent or the capacity to respond or cope with a risk event (Zhang, 2007). Barber (2005) accepts the rules, policies, processes, structures, actions, decisions, behaviors or culture within the project organization or its hosts as internally generated risks. He mentions the fact that imperfect organizations or systems generate new risks but in traditional risk management process these are considered to be less important. As the actual consequences of risk events depend on an organization's capability to manage risks, the company factors as well as the project characteristics that affect project vulnerability should be taken into account during risk identification.

3.1.2. Identification of Risk Paths

3.1.2.1. Identification of Risk Sources

A number of authors have described the risk sources specific to international construction projects which are very sensitive to regional conditions such as currency devaluation, currency exchange restrictions, cultural differences, and unstable laws or regulations (Pinto and Mantel 1990; Zhi 1995; Bing and Tiong 1999; Wang et al. 2000; Hastak and Shaked 2000; Han and Diekmann 2001; Tah and Carr 2001; Chan et al. 2001; Kapila and Hendrickson 2001; Cano and Cruz 2002; Chan and Tse 2003, Baloi and Price 2003). More specifically, Henroid et al. (1984) and Wolf (1988) summarized political and economic risk sources that affect the developing countries. Similarly, Jaselskis and Talukhaba (1998) investigated the risk sources that the developing countries were subject to and came up with government instability, shortages of adequately trained craftsmen, difficulty in acquiring needed materials, and lack of adequate infrastructure.

Lee and Walters (1989) and ICAK (2002) outlined risk causes of damages/losses in international construction projects as nonpayment by foreign governments due to a lack of funds or economic crises; low profitability due to the competitive bidding process, misunderstanding of contract provisions or specification requirements; miscommunication with foreign governments; local currency devaluation; unfair contract clauses; unexpected weather; labor, and material supply; lack of experience and inability to perform; conflicts among clients, engineers, contractors, and local subcontractors; excessive burden of banking and insurance cost; failure to manage cash flow; and damages due to inappropriate partners. Henninger (1998) identified five sources of risk which influence vulnerability: environmental risk (droughts, floods, and pests), market risk (price fluctuations, wage variability, and unemployment), political risk (changes in subsidies or prices, income transfers, and civil strife), social risk (reduction in community support and entitlements), and health risk (exposure to diseases that prevent work).

Risk sources used in the construction of risk paths throughout this study have been decided based on the risks identified in the previous studies. As the intent of previous works differ from the aim of this one, all risk factors/sources obtained from the literature will be eliminated considering their adequacy and applicability in the development of risk paths for this particular study. The final risk sources that are acquired after this elimination will take place on the risk paths.

First of all, the basic categories for the risks are identified and the HRBS is constructed based on the pre-defined risk sources (Figure 1). The taxonomy starts with dividing the risk sources into two as Risk Sources-1 (R1) and Risk Sources-2 (R2). R1 stands for potential "changes" in country conditions as well as project-related factors with respect to economic, legal, political, client, technical, company, other parties, and external conditions while R2 denotes the risks caused by force majeure and unexpected conditions. The final risk sources and the studies in which they were mentioned are shown in Table 3.

The risk sources shown in Table 3 are only the ones taken from previous studies. In addition to these causes; change in financial conditions, performance, relations, and staff of engineer under parties category; change in requirements under technical category; change in objectives under company category; and epidemic disease under force majeure category are added to the risk source list.

It is obvious that defining risk sources based on literature review is not enough and the risk causes should be verified. In this research this is achieved by conducting interviews and collecting data for various cases.

Case study research is carried out for both justification of the pre-defined risk paths and checking the reliability of risk-vulnerability framework. For constructing both risk paths and the proposed model, risk events and consequences together with vulnerability parameters will be investigated in the following steps.

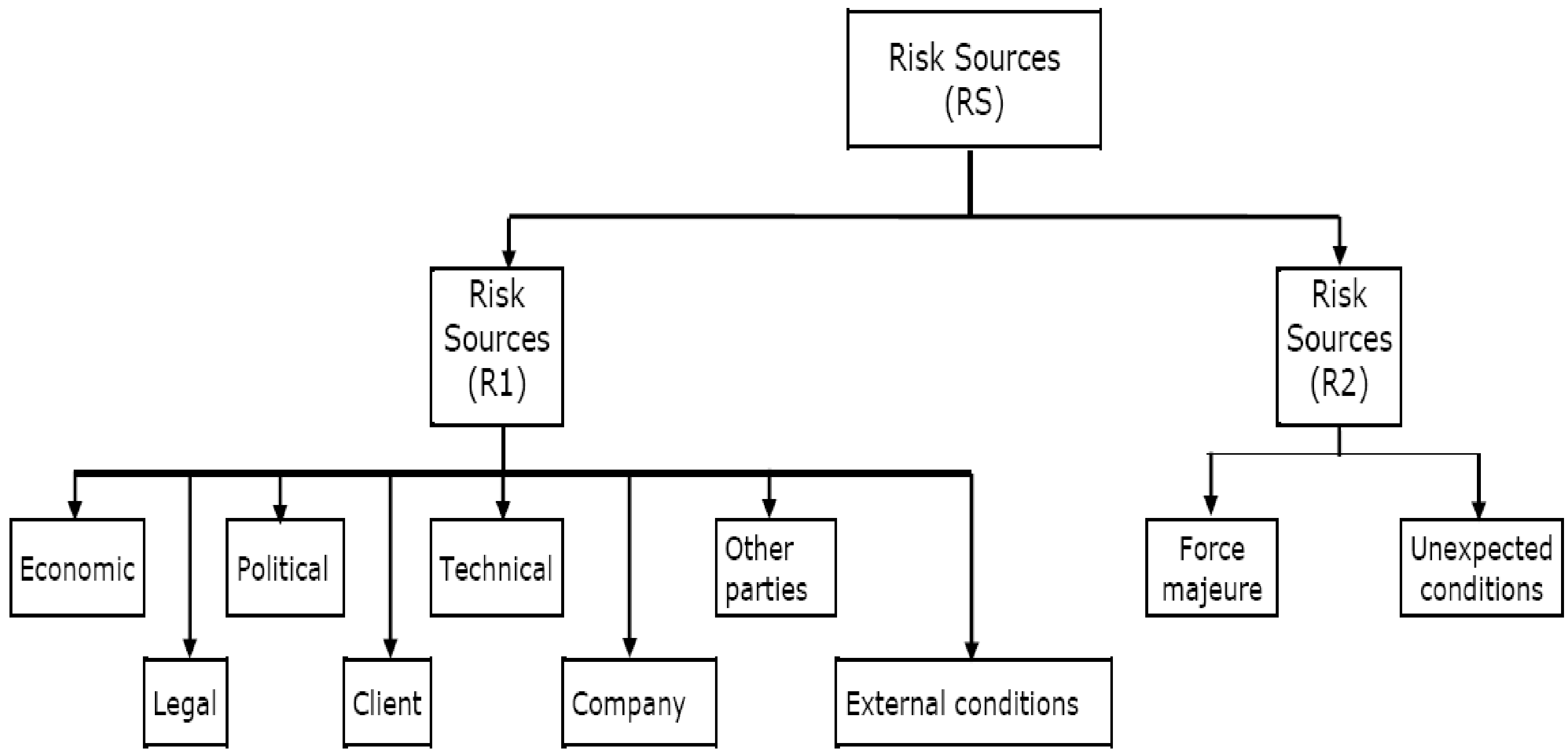

Figure 1: Risk Source Taxonomy

Table 3: The Final Risk Sources and Corresponding Articles

RISK SOURCES-1 (R1)				CORRESPONDING ARTICLES
COUNTRY	Economic	Change in	currency rates	Ashley and Bonner (1987), Han and Diekmann (2001), Jaselskis and Talukhaba (1998), McConville (1996) cited in Gunhan and Arditi (2005), Al-Bahar and Crandall (1990), Han et al. (2007), Chua et al (2003), Fraser and Fraser (2002), Chapman (2001), Rosenbaum (1997) cited in Baloia and Price (2003), Leung et al. (1998), Hillson (2003), Frimpong et al. (2003)
			inflation	Han and Diekmann (2001), Hastak and Shaked (2000), Chua et al (2003), Birgonul and Dikmen (2001), Jaselskis and Talukhaba (1998), Al-Bahar and Crandall (1990), Chapman (2001), Akinci and Fisher (1998), Leung et al. (1998), Frimpong et al. (2003)
			interest rates	Jaselskis and Talukhaba (1998), Rosenbaum (1997) cited in Baloia and Price (2003), Han and Diekmann (2001)
			tax rates	Hastak and Shaked (2000), Ashley and Bonner (1987), Arditi and Gutierrez (1991), Han and Diekmann (2001), Chua et al (2003), Jaselskis and Talukhaba (1998), Birgonul and Dikmen (2001), Jaafari (1998) cited in Jaafari (2001), Henroid et al. 1984 cited in Bing et al. (1999)
	Legal	Change in	laws & regulations	Ashley and Bonner (1987), Han and Diekmann (2001), Chua et al (2003), Jaselskis and Talukhaba (1998), Chan and Tse (2003), Al-Bahar and Crandall (1990), Chapman (2001), Kaming (1997) cited in Baloia and Price (2003), Jaafari (1998) cited in Jaafari (2001), Leung et al. (1998), Hall and Hulett (2002) cited in Hillson (2003), Fraser and Fraser (2002), Han et al. (2007), Dikmen and Birgonul (2006), Odeh and Battaineh (2002)
	Political	Change in	government's policy	Ashley and Bonner (1987), Chua et al (2003), Fraser and Fraser (2002), Arditi and Gutierrez (1991), Jaselskis and Talukhaba (1998)
			government's attitude to foreign investors	Han et al. (2007), Chapman (2001), Chua et al (2003), Han and Diekmann (2001), Jaselskis and Talukhaba (1998)

Table 3: The Final Risk Sources and Corresponding Articles (cont'd)

RISK SOURCES-1 (R1)				CORRESPONDING ARTICLES
PARTIES	Client	Change in	attitude	Han et al. (2007), Chapman (2001), Jahren and Ashe (1990), Hillson (2003)
			expectations/objectives	Birgonul and Dikmen (2001), Han et al. (2007), Kometa et al. (1995), Rosemond (1984) cited in Jahren and Ashe (1990), Chapman (2001), Baloia and Price (2003), Kometa et al. (1995), Leung et al. (1998), Odeh and Battaineh (2002)
			financial conditions	Hastak and Shaked (2000), Han and Diekmann (2001), Jaselskis and Talukhaba (1998), Fraser and Fraser (2002), Barco (1994), Dikmen and Birgonul (2006), Al-Bahar and Crandall (1990), Chapman (2001), Han et al. (2007), Jaafari (1998) cited in Jaafari (2001), Kometa et al. (1995), Hall and Hulett (2002) cited in Hillson (2003), Birgonul and Dikmen (2001), Odeh and Battaineh (2002)
			staff	Chapman (2001), Frimpong et al. (2003)
	Designer	Change in	financial conditions	Akinci and Fisher (1998), Ibbs and Ashley (1987) cited in Akinci and Fisher (1998), Leung et al. (1998)
			performance	Dikmen and Birgonul (2006)
			relations	Birgonul and Dikmen (2001), Chapman (2001), Odeh and Battaineh (2002)
			staff	Birgonul and Dikmen (2001), Chapman (2001), Odeh and Battaineh (2002), Frimpong et al. (2003)

Table 3: The Final Risk Sources and Corresponding Articles (cont'd)

RISK SOURCES-1 (R1)				CORRESPONDING ARTICLES
PARTIES	Partner	Change in	financial conditions	Hastak and Shaked (2000), Han and Diekmann (2001), Jaselskis and Talukhaba (1998), Fraser and Fraser (2002), Barco (1994), Dikmen and Birgonul (2006), Al-Bahar and Crandall (1990), Chapman (2001), Han et al. (2007), Jaafari (1998) cited in Jaafari (2001), Kometa et al. (1995), Hall and Hulett (2002) cited in Hillson (2003)
			performance	Dikmen and Birgonul (2006)
			relations	Han et al. (2007), Odeh and Battaineh (2002)
			staff	Frimpong et al. (2003)
	Subcontractor	Change in	financial conditions	Akinci and Fisher (1998), Ibbs and Ashley (1987) cited in Akinci and Fisher (1998), Leung et al. (1998)
			performance	Dikmen and Birgonul (2006), Akinci and Fisher (1998), Leung et al. (1998)
			relations	Chua et al (2003), Odeh and Battaineh (2002)
			staff	Odeh and Battaineh (2002), Frimpong et al. (2003)
TECHNICAL		Change in	construction methods/technology	Hastak and Shaked (2000), Han and Diekmann (2001), Fraser and Fraser (2002), Odeh and Battaineh (2002)
			design	Al-Bahar and Crandall (1990), Ibbs and Ashley (1987) cited in Akinci and Fisher (1998), Leung et al. (1998)
			material	Frimpong et al. (2003)
COMPANY		Change in	financial conditions	Frimpong et al. (2003)
			performance	Han and Diekmann (2001), Han et al. (2007)
			relations	Frimpong et al. (2003)
			staff	Frimpong et al. (2003)
			top management support	Frimpong et al. (2003)

Table 3: The Final Risk Sources and Corresponding Articles (cont'd)

RISK SOURCES-1 (R1)			CORRESPONDING ARTICLES
EXTERNAL CONDITIONS	Change in	weather conditions	Hastak and Shaked (2000), Han and Diekmann (2001), Jaselskis and Talukhaba (1998), Birgonul and Dikmen (2001), Al-Bahar and Crandall (1990), Han et al. (2007), Kaming (1997) cited in Baloia and Price (2003), Akinci and Fisher (1998), Leung et al. (1998), Hillson (2003), Dikmen and Birgonul (2006), Odeh and Battaineh (2002), Frimpong et al. (2003)
		geological conditions	Hastak and Shaked (2000), Han and Diekmann (2001), Jaselskis and Talukhaba (1998), Birgonul and Dikmen (2001), Akinci and Fisher (1998), Leung et al. (1998), Odeh and Battaineh (2002), Frimpong et al. (2003)
		public reaction	Han and Diekmann (2001), Chan and Tse (2003), Fraser and Fraser (2002), Dikmen and Birgonul (2006), Leung et al. (1998), Hastak and Shaked (2000), Ashley and Bonner (1987)
		site conditions-accessibility	Jaselskis and Talukhaba (1998), Dikmen and Birgonul (2006), Al-Bahar and Crandall (1990), Han et al. (2007), Chapman (2001), Baloia and Price (2003), Leung et al. (1998), Odeh and Battaineh (2002), Frimpong et al. (2003)
		international relations	Han and Diekmann (2001), Birgonul and Dikmen (2001), Dikmen and Birgonul (2006)
RISK SOURCES-2 (R2)			
FORCE MAJEURE	War/hostilities		Hastak and Shaked (2000), Ashley and Bonner (1987), Han and Diekmann (2001), Fraser and Fraser (2002), Al-Bahar and Crandall (1990), Jaafari (1998) cited in Jaafari (2001), Odeh and Battaineh (2002)
	Rebellion/terrorism		Hastak and Shaked (2000), Ashley and Bonner (1987), Han and Diekmann (2001), Fraser and Fraser (2002), Al-Bahar and Crandall (1990), Jaafari (1998) cited in Jaafari (2001)

Table 3: The Final Risk Sources and Corresponding Articles (cont'd)

RISK SOURCES-2 (R2)		CORRESPONDING ARTICLES
FORCE MAJEURE	Social unrest	Hastak and Shaked (2000), Ashley and Bonner (1987), Han and Diekmann (2001), Dikmen and Birgonul (2006), Al-Bahar and Crandall (1990), Jaafari (1998) cited in Jaafari (2001), Leung et al. (1998), Chua et al (2003), Han et al. (2007)
	National catastrophes (earthquake, hurricanes, volcanic activity, typhoon, flood, fire, landslide, wind, lightning etc.)	Al-Bahar and Crandall (1990), Baloia and Price (2003), Leung et al. (1998), Jaselskis and Talukhaba (1998), Staab (1989)
	Historical findings	Chapman (2001)
UNEXPECTED CONDITIONS	Accidents	Al-Bahar and Crandall (1990)
	Damage to site	Al-Bahar and Crandall (1990)
	Breakdown of machinery	Hastak and Shaked (2000), Birgonul and Dikmen (2001), Odeh and Battaineh (2002), Frimpong et al. (2003)
	Theft	Al-Bahar and Crandall (1990), Baloia and Price (2003)
	Strikes/labor problems	Hastak and Shaked (2000), Ashley and Bonner (1987), Han and Diekmann (2001), Dikmen and Birgonul (2006), Al-Bahar and Crandall (1990), Jaafari (1998) cited in Jaafari (2001), Leung et al. (1998), Chua et al (2003), Han et al. (2007)

3.1.2.2. Definition of Risk Events and Consequences

In defining risk events, all types of pre-mentioned risk sources should be considered to affect productivity, performance, quality, and economy of construction (Al-Bahar and Crandall, 1990). In this study, risk events are mainly about "variations (decrease or increase)" about productivity, quantity of work, relations etc. The factors considered under each category are given in Table 4.

Table 4: Risk Events (RE)

Category	Factors
Productivity	Decrease/increase in productivity
Quantity	Decrease/increase in quantities
Quality	Decrease/increase in quality
Unit cost of resources	Decrease/increase in unit cost of resources
Delay	Delay in bureaucracy, approvals, site handover, decision-making, logistics, progress payments
Relations	Conflict between parties, company and client

On the other hand, risk consequence is mainly concerned with financial gain/loss together with personal injury, physical damage, time and cost savings/overrun (Al-Bahar and Crandall, 1990). According to Walewski and Gibson (2003), if international projects can not meet the requirements in scope, budget, and schedule, serious consequences will be in economic, social, and political issues. Indeed, risk sources affect the risk events and cause changes in the system's performance measures—duration, cost, quality, and safety (Tah and Carr, 2000).

In this research, risk consequences are defined based on the assumption that there are four project success criteria: cost, schedule, level of client satisfaction and disputes between the parties. The factors of each project success criteria are given in Table 5. It is clear that the contents of this category can be revised by incorporating other success criteria (such as health and safety issues etc.) which can be valid for particular project cases.

Table 5: Risk Consequences (RC)

Category	Factors
Cost	Impact on cost
Schedule	Impact on project duration
Client satisfaction	Impact on level of client satisfaction
Disputes	Impact on level/number of disputes

3.1.2.3. Construction of Risk Paths

The risk paths are identified referring to previous projects carried out by Turkish contractors in international markets as well as a detailed literature survey on risks in international projects. The path occurs between risk sources, events and consequences. One or more risk sources may result in one or more risk events to occur and they result in one or more risk consequences. For example, change in weather conditions (R1) and social unrest (R2) cause decrease in productivity (RE) which results in increase in project duration (RC). Figure 2 shows an example of a risk path that result in decrease in productivity and increase in project duration. Different risk paths may emerge in construction companies depending on the level of vulnerability and uncertainty. Actually, each path is a possible scenario that can happen in a construction project. The aim of this study is to determine the major elements of risk paths such as sources of risk, factors of vulnerability etc. so that all possible scenarios that can be encountered in construction projects are covered.

In the forthcoming stages of this research project, hypothetical as well as some real cases will be defined considering different levels of vulnerability-risk and their interrelations. Expert judgments will be used to validate the structure of paths.

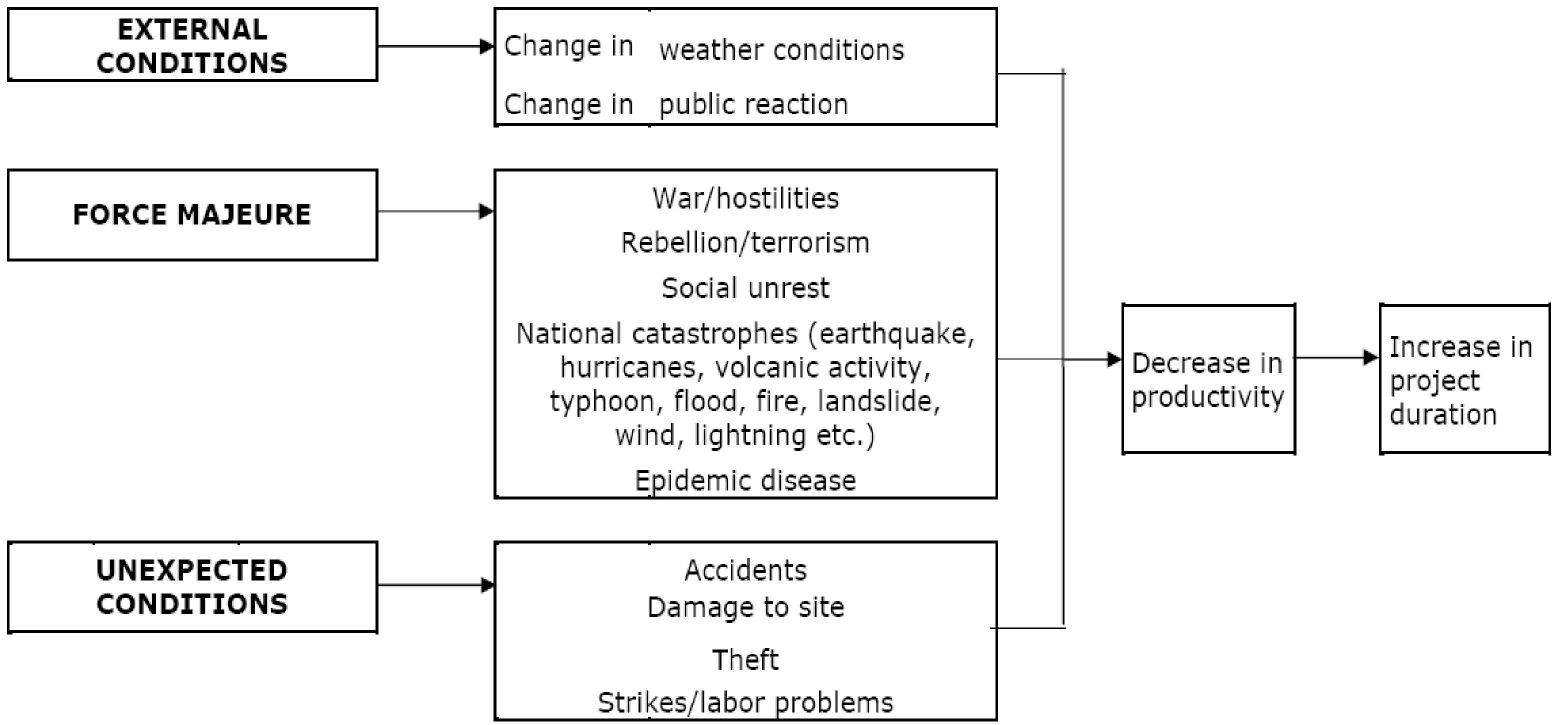

Figure 2: An Example of Risk Path

3.1.3. Identification of Vulnerability Parameters

Ezell et al. (2000a, 2000b) showed that an important component of risk assessment is determining the vulnerability of a system. Vulnerable systems are systems that are exposed, accessible, and therefore susceptible to natural hazards as well as willful intrusion, tampering, or terrorism (NSTAC, 1997).

There exists a relationship between risk and vulnerability that can be observed from literature. Magnitude of risk depends on the probability and impact which is also defined as severity of a scenario while vulnerability shows the susceptibility to that scenario (Ezell, 2007). Dikmen et al. (2007) believe that factors about manageability, which are regarded as vulnerability parameters in this study, set the connection between risk sources and consequences. Therefore they emphasize the importance of identifying and storing the response strategies, decisions, actions, resources, capabilities, contract and project-related factors. Similarly, Cano and Cruz (2002) state that PRM must be shaped specific to the project and organization responsible for it, and therefore the organization's risk maturity and the project complexity and size, among other factors should be considered. Fan et al. (2007) summarizes project characteristics which could affect the cost of different actions and handling strategy as project size, technological complexity, level of schedule slack, and external economic and political factors.

The grouping of vulnerability starts with Chambers (1983, 1989) who makes a distinction between "internal" and "external" risks. It is stated that: "Vulnerability has two sides: an external side of risks, shocks, and stress to which an individual is subject to; and an internal side which is defenceless, meaning a lack of means to cope without damaging loss"

(Chambers, 1989). Afterwards, Watts and Bohle's (1993) defined the "space of vulnerability" to be exposure (risk of exposure to hazards) as the external side of vulnerability, whilst capacity (risk of inadequate capacity to mobilize resources to deal with hazards) and potentiality (the risk of severe consequences) form a more complex understanding of the internal side of vulnerability.

In this research, factors related with the contract, project, company and project parties are identified to indicate a system's vulnerability (Dikmen et al., 2008). The vulnerability parameters to be used in the proposed risk-vulnerability framework are shown in Table 6.

Table 6: Vulnerability Parameters

Category	Sub-category	Factors
Contract	Clauses	Rights and obligation of parties, payment method, escalation, taxation, warranty, default of owner, force majeure, cost compensation, time extension, liquidated damages, change orders, variation of work, valuation of variations, disputes, codes and standards, etc.
Project	Project-requirements	Technical, technological, managerial, quality, health and safety, environmental impact
	Project-conditions	Design maturity, constructability, geotechnical conditions, location, site conditions, contract clarity, scope clarity, size, duration, payment type, project delivery system
	Country-market conditions	Labor, material, equipment, local supplier, local subcontractor, infrastructure
	Country-requirements	Import-export rules, customs procedures, social security law, requirements from foreign firms (such as hiring local labor, partnering with local firms, etc.)

Table 6: Vulnerability Parameters (cont'd)

Category	Sub-category	Factors
Project	Country-conditions	Political and economic stability, legal system maturity, socio-cultural differences, international relations, bureaucracy, significance of the project for the country, geography and climate conditions, government attitude toward foreign investors.
Company	Company-resources	Financial and technical resources, staff, managerial capability, experience, relations (with client, government, partners etc.)
	Company-conditions	Objectives, management capability (such as planning, organization, documentation, control and monitoring, leadership etc.), risk response strategy, workload, business style, management style, top management support, location of management (headquarter vs. regional branch)
Project parties	Client-resources	Financial strength, staff, experience
	Client-conditions	Significance of the project, clarity of objectives, management capability, risk response strategy, relations with contractor
	Other parties (Partner, designer, subcontractor, engineer, supplier etc.) -resources	Financial strength, experience, staff, cultural differences, Management capability, risk response strategy, relations with the client and government

Table 6 includes the most significant contract clauses that will make the projects more or less vulnerable to risk events together with project characteristics which basically include project requirements, restrictions, standards, project size, duration, site and country conditions. Moreover, company characteristics such as project management system's maturity, project managers and team's abilities, experience and strength also have effects on the risk consequences. Finally, key project participants including client, partner, subcontractor, supplier, designer and engineer are shown in Table 6 as the abilities, workload, financial strength of each party and the relations between these parties will influence project outcomes.

3.1.4. The Proposed Risk and Vulnerability Model

Based on the above discussions, the proposed risk-vulnerability paths are determined based on a detailed literature survey on international construction projects. The proposed risk-vulnerability framework is shown in Figure 3.

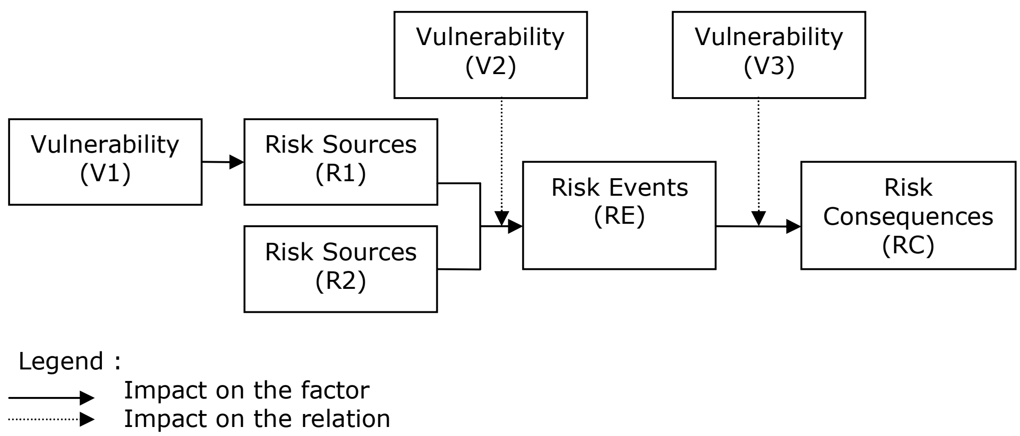

Figure 3: Risk and Vulnerability Paths

As stated before, risk sources are classified in two different categories in Figure 3; R1 and R2. R1 refers to potential “changes”. Changes in country conditions as well as project-related factors are considered in this category. On the other hand, unexpected conditions such as force majeure events are placed under R2. Risk events are mainly about “variations (decrease or increase)” about productivity, quantity of work, relations etc. The factors considered under each category are given in Table 7.

As presented in Figure 3, some of the vulnerability factors affect the probability of occurrence of risks whereas the others affect only the relations between risk sources, events and consequences. Vulnerability factors may influence the level of risk in three ways:

- Vulnerability (V1) refers to the factors that affect the probability of occurrence of risk. For example, if the owner’s objectives are not clear, this will increase the risk of “change in scope”.
- Vulnerability (V2) refers to the factors that affect manageability of risk. For instance, “change in construction technology” may lead to a less significant risk event (such as delay) if the company has the necessary know-how and an adequate change management system.
- Vulnerability (V3) refers to the factors that influence the impact of risk events on project success. In other words, those are the factors which affect the magnitude of risk consequences. For instance, if there is an increase in the quantity of work due to change in scope, the implications for the contractor are different in case the contract/payment type is unit-price or lump-sum.

Table 7: Risk and Vulnerability Factors

Category	Sub-(sub)category	Factors
Vulnerability (V1)	Project-requirements	Technical, technological, managerial, quality, health and safety, environmental impact
	Project-conditions	Design maturity, constructability, geotechnical conditions, location, site conditions, contract conditions
	Country-market conditions	Labor, material, equipment, local firms, infrastructure
	Country-requirements	Import-export rules, customs procedures, social security law, requirements from foreign firms such as hiring local labor, partnering with local firms
Vulnerability (V1)	Country-conditions	Political and economic stability, legal system maturity, socio-cultural differences
	Company-resources	Financial and technical resources, staff, managerial capability, experience, relations (with client, government, partners etc.)
	Company- conditions	Objectives, strategies, workload
	Client-resources	Financial strength, staff, experience
	Client-conditions	Significance of the project, objectives, strategies
	Other parties (Partner, designer, subcontractor, engineer, supplier etc.)-resources	Financial strength, experience, staff, cultural differences, relations with the client and government
Risk Sources (R1)	Economic	Change in currency rates, inflation, interest rates, tax rates
	Legal	Change in laws and regulations
	Political	Change in government's policy, government's attitude to foreign investors
	Client	Change in staff, expectations/objectives, financial conditions, attitude

Table 7: Risk and Vulnerability Factors (cont'd)

Category	Sub-(sub)category	Factors
Risk Sources (R1)	Technical	Change in construction methods/technology, design, materials, requirements
	Company	Change in performance, staff, financial conditions, top management support, objectives, relations
	Other parties	Change in performance, staff, financial conditions, relations
	External conditions	Change in weather conditions, geological conditions, public reaction, site conditions-accessibility, international relations
Risk Sources (R2)	Force majeure	War/hostilities, rebellion/terrorism, social unrest, national catastrophes (earthquake, hurricanes, volcanic activity, typhoon, flood, fire, landslide, wind, lightning etc.), historical findings, epidemic disease
	Unexpected conditions	Accidents, damage to site, breakdown of machinery, theft, strikes/labor problems
Vulnerability (V2)	Company	Management capability (such as planning, organization, leadership etc.), risk response strategy
	Other parties	Management capability, risk response strategy
Risk Events (RE)	Productivity	Decrease/increase in productivity
	Quantity	Decrease/increase in quantities
	Quality	Decrease/increase in quality
	Unit cost of resources	Decrease/increase in unit cost of resources
	Delay	Delay in bureaucracy, approvals, site handover, decision-making, logistics, progress payments
	Relations	Conflict between parties, company and client
Vulnerability (V3)	Contract clauses	Contract clauses about escalation, cost compensation, time extension, liquidated damages, change orders etc.
	Project	Size, duration, payment type, project delivery system

Table 7: Risk and Vulnerability Factors (cont'd)

Category	Sub-(sub)category	Factors
Risk Consequence (RC)	Cost	Impact on cost
	Schedule	Impact on project duration
	Client satisfaction	Impact on level of client satisfaction
	Disputes	Impact on level/number of disputes

It should be noted that, all factors under a specific category are not necessarily affected from all factors given under the preceding category. For example, all of the factors under R1 are not influenced by V1. There are individual relations between the factors leading to a number of risk-vulnerability paths some of which coincide whereas others are completely independent. The risk-vulnerability factors are defined from the perspective of the contractor and will be improved by conducting interviews for particular project cases. Although, the level of vulnerability may be different among contractors from different parts of the world and magnitude of risk may differ from project to project, it is believed that the components of risk and vulnerability are similar in all conditions. Previous projects carried out by Turkish contractors in international markets will be used for verification of this model in the following chapter.

CHAPTER 4

VERIFICATION OF THE GENERIC RISK AND VULNERABILITY MODEL: CASE STUDIES

Up to this point, a set of factors and a categorical structure for risk and vulnerability assessment are presented. Although it is based on an extensive literature survey, the assessment has to be validated by referring to real cases. Various case studies were conducted to understand the components and basic relations between the factors of risk and vulnerability. In this chapter, the properties and exemplification of these case studies are depicted in detail.

4.1. General Properties of Case Studies

In the scope of this research five real case studies were conducted through interviews. The general properties of the five case studies are shown in Table 8.

Table 8: General Properties of the Case Studies

Project			Payment Type	Type of Partnership
No	Location	Type		
1	Jordan	Process Plant	Lump sum	Joint Venture (JV)
2	Dubai (the United Arab Emirates)	Infrastructure (sewer system)	Unit price	Consortium
3	Dubai (the United Arab Emirates)	Building (Villas)	Unit price	Joint Venture (JV)
4	Afghanistan	Building	Unit price	Joint Venture (JV)
5	Turkey	Infrastructure (Dam)	Unit price + Lump sum	Consortium

In all of the case studies FIDIC is the reference contract. Therefore, vulnerability parameters are chosen based on FIDIC contract clauses. Project delivery system is defined as Design-Build in most of the cases indicating that the design and construction aspects are contracted to a single entity. In all of the cases, the single entity is either the contractor or the partner one of whom performs design and construction. The fifth case study as shown in Table 8 is about an international project carried out by an Austrian company and a Turkish company, thus, it is defined as an international project.

The interviews were performed by the cooperate work of two interviewers. Both of the interviewers were research assistants and one of whom was the writer of this thesis. The interviews were conducted in two phases. In the first phase the interviewee was asked to give general information (e.g. location, type, etc.) about the project and explain the adverse situations experienced throughout this project. By this way, the country, market, project and company characteristics causing risk events and consequences were mentioned in a path-wise manner. In the second phase, questions were asked to verify the occurrence of several risky scenarios that are taken from the literature survey. Meanwhile, the company risk mitigation strategies and the final impact on the risk consequence were tried to be learned.

The interview for a single project took approximately one and a half hour. The conversations were recorded with the permission of the interviewee. The tape records were listened for several times for each project in order to sort out the risk and vulnerability parameters. The factors mentioned by the interviewees were tried to be matched with the pre-defined ones based on the literature survey. The parameters deviating from the pre-defined ones were noted to be used in the further improvement of the model. All of the parameters mentioned for each project were utilized in the construction of sample risk and vulnerability paths. A total of five project data were collected and investigated for revealing the interrelations of risk and vulnerability factors in real cases. In the following parts of this chapter, the data obtained from the five real case studies will be explained and presented in Figures 5 to 9.

4.2. Case Studies

4.2.1. Case Study 1

The first interview was carried out about a process plant project in Jordan. The budget of the project is $80.000.000 and it has been completed recently. The main two reasons resulting in a problematic situation is explained as the technical complexity of the project (type of the project as process plant) and payment method (the type of the payment as lump sum). These two reasons are reflected in several vulnerability parameters and the problematic events that have occurred are demonstrated as risk sources and events. The schematic representation of risk and vulnerability paths of this project is given in Figure 4.

In Figure 4, several risk and vulnerability parameters, which are mentioned by the interviewee for this specific project, are shown. The vulnerability factors caused from the country, project, party, and company conditions are summarized in the Vulnerability 1 (V1) group. With the effect of V1 parameters, Risk Sources (RS) take place. The managerial capacities of company, client and parties in the Vulnerability 2 (V2) group affect the increase/decrease or delay in several items that are included in the Risk Event (RE) group. The impact of risk response strategies in the Vulnerability 3 (V3) group, results in the final Risk Consequence (RC) such as increase in project cost and/or duration. All the information given about the contents of V1, V2, and V3 parameters and their relations with RS, RE and RC are valid for all of the five case studies.

The first important point in investigating Figure 4 is that not all of the parameters in V1 group cause the occurrence of all of the factors in RS group. For example, level of bureaucracy and restrictions for foreign company (V1) causes poor relations with the government (RS), but the complexity of design or incomplete design (V1) has no relation with the formation of this risk factor. The second important point is that a path starting from V1 does not need to follow RS, RE, RC, and other vulnerabilities subsequently. Therefore, additional arrows are defined from V1 to RE, RS to V3, and V2 to V3 according to the information gained from the interviewee. For instance, the risk and vulnerability path starting from level of bureaucracy and restrictions for foreign company (V1) continues with giving rise to poor relations with the government (RS), and considering the managerial capacities of company, client and parties (V2) and the effect of increasing the number of staff (V3), the path ends with increase in project duration (RC). As it can be easily observed, there is no RE in this path. Another path initiates from lack of experience in similar projects and with the client (V1) and causes inadequacy in fulfilling client's requirements (RS). Then, considering the managerial capacities of company, client and parties (V2), delay in progress payments (RE) occurs. Although the number of meetings are increased (V3), there is increase in project duration (RC). This path includes all the members of the risk and vulnerability structure. Similar risk and vulnerability paths can be observed from Figure 4 for this project.

4.2.2. Case Study 2

The second interview was performed about an infrastructure project in Dubai (the United Arab Emirates). The problematic issues in this project are mostly caused by the contract clauses, country conditions and financial issues. There is also unavailability of resources and imperfections in project management capacities which result in risky situations. The risk and vulnerability paths for this project are shown in Figure 5.

An instance of risk and vulnerability path can be observed by inadequate climate conditions (V1) resulting in adverse weather conditions (RS). Although the managerial capacities of company, client and parties (V2) are applied to the model, an increase in project duration (RC) is experienced as there are no risk response strategies (V3). Another path is performed by vagueness of contract clauses and contract errors (V1) which cause poor relations with the client and inadequacy in fulfilling the client’s requirements (RS); thinking of the managerial capacities of company, client and parties (V2), increase in quantity of work and delay in bureaucracy (RE) occurs; and with the effect of the increase in the number of staff (V3), the path results in increase in project cost and duration. In a similar manner, the remaining risk and vulnerability paths can be observed from Figure 5 for this project.

4.2.3. Case Study 3

The third interview was made with an interviewee who gave information about two projects. The first one is a building project in Dubai (the United Arab Emirates). This project has its main problems because of the unordered submission of work items. The illustration of risky situations is given in Figure 6.

An example risk and vulnerability path for this project starts with lack of experience in PDS and lack of technical resources and staff (V1). This causes change in project team (PM, technical office members) (RS) and when the managerial capacities of company, client and parties (V2) are thought and organization/staff is changed (V3), this path results in increase in project duration (RC). Another one is caused by unavailability of local material (V1). Then unavailability of material (RS) takes place and considering the managerial capacities of company, client and parties (V2), extra parties are hired (V3) and this brings increase in project cost. Similarly, the remaining risk and vulnerability paths can be observed from Figure 6 for this project.

4.2.4. Case Study 4

The second project told by the same interviewee is a building project in Afghanistan. Nearly all of the problems in this project are caused by the insecure environment in Afghanistan because of war. The risk and vulnerability paths of this project are shown in Figure 7.

A sample risk and vulnerability path here starts by level of mafia power, unavailability of local material, equipment, labor, subcontractor, and infrastructure (V1) which causes change in scope, change in original schedule/sequence, change in site organization, and unavailability of labor, material, equipment and subcontractor (RS). With the effect of the managerial capacities of company, client and parties (V2) increase in unit cost of resources and delay in logistics (RE) occur. As a result of no response (V3), increase in project cost and duration (RC) come into the picture. In a similar manner, the remaining risk and vulnerability paths can be observed from Figure 7 for this project.

4.2.5. Case Study 5

The last interview was done about an infrastructure (dam) project constructed in Turkey by a Turkish-Austrian consortium. Most of the problems are caused by the poor relations of the Austrian partner with the government and the cultural conflicts between partners. The risks and vulnerabilities concerning the projects are shown in Figure 8.

A section of risk and vulnerability path starts because poor accessibility of site and inadequate geological investigation (V1). This results in adverse geological conditions because of the seepage caused by the problems of the cutoff wall and unavailability of equipment (RS). When the managerial capacities of company, client and parties (V2) are considered, increase in quantity of work and delay in logistics (RE) take place. There is no response (V3) as the delay is caused by very special equipment that is counted as 4-5 numbers worldwide. Finally, the impact is increase in project cost and duration (RC). Another path is caused by instability of international relations and level of bureaucracy (V1) which continues with poor relations with the government and partner (RS). Considering the effect of the managerial capacities of company, client and parties (V2), delay in bureaucracy (RE) happens. As there is no response to RE, outcome becomes increase in the project cost and duration (RC). Similarly, the remaining risk and vulnerability paths can be observed from Figure 8 for this project.

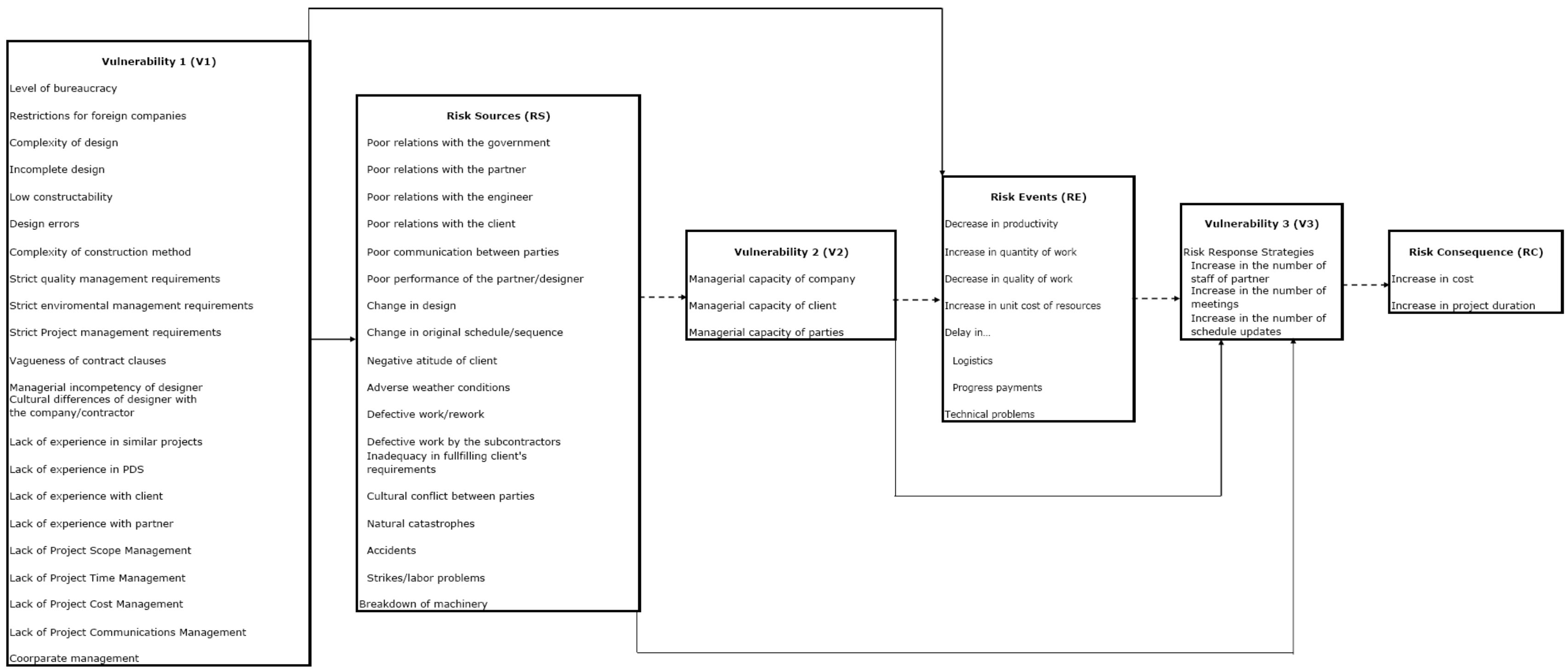

Figure 4: Risk and Vulnerability Paths for Case Study 1

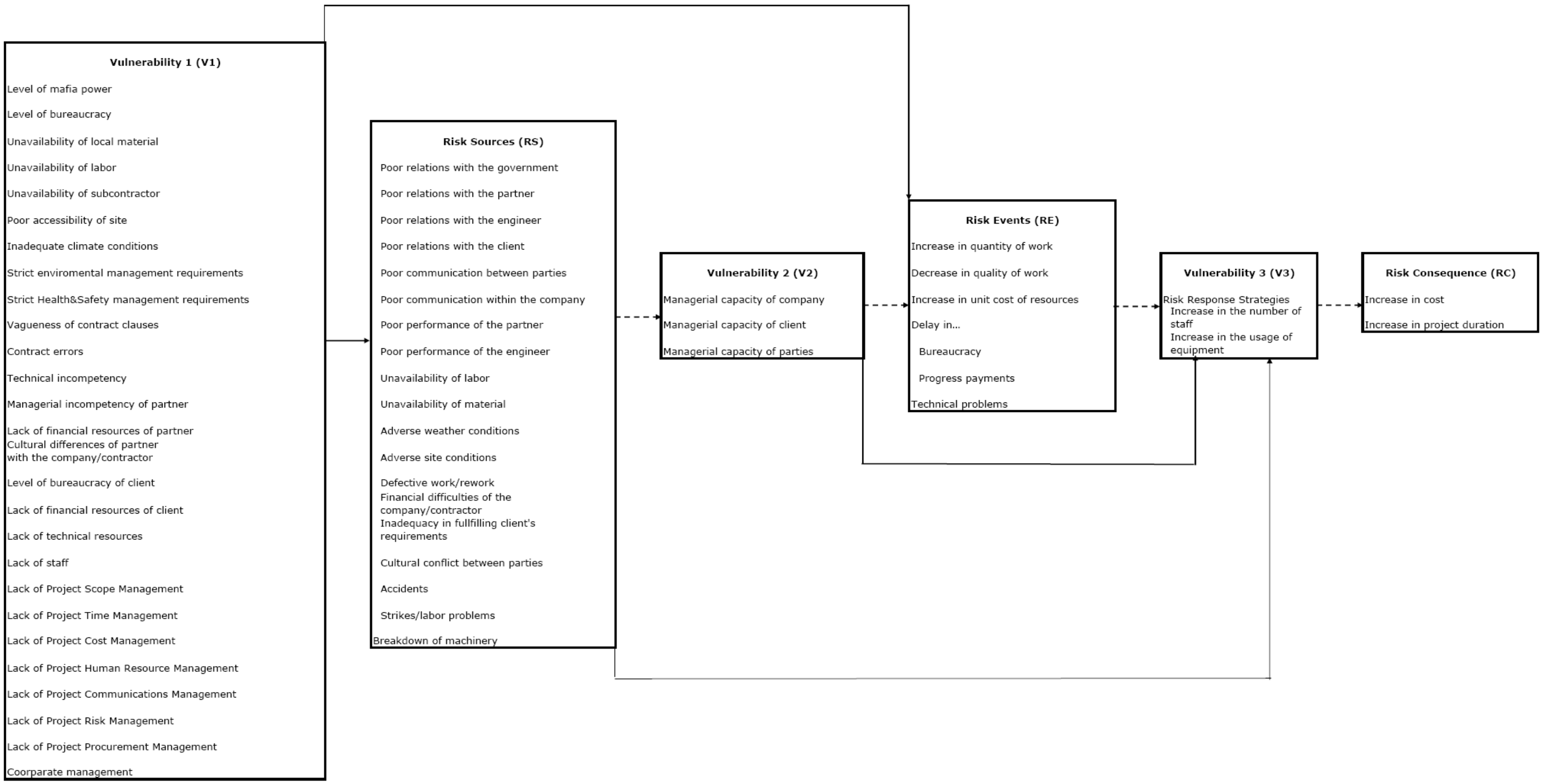

Figure 5: Risk and Vulnerability Paths for Case Study 2

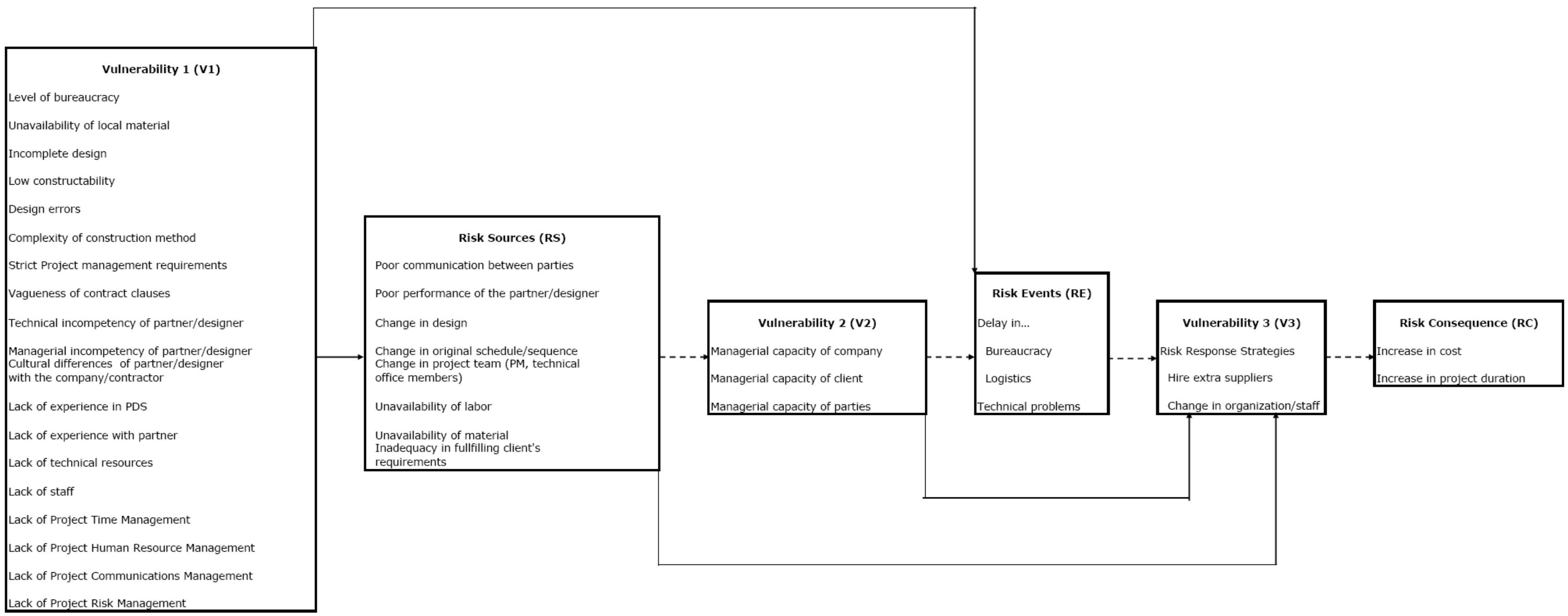

Figure 6: Risk and Vulnerability Paths for Case Study 3

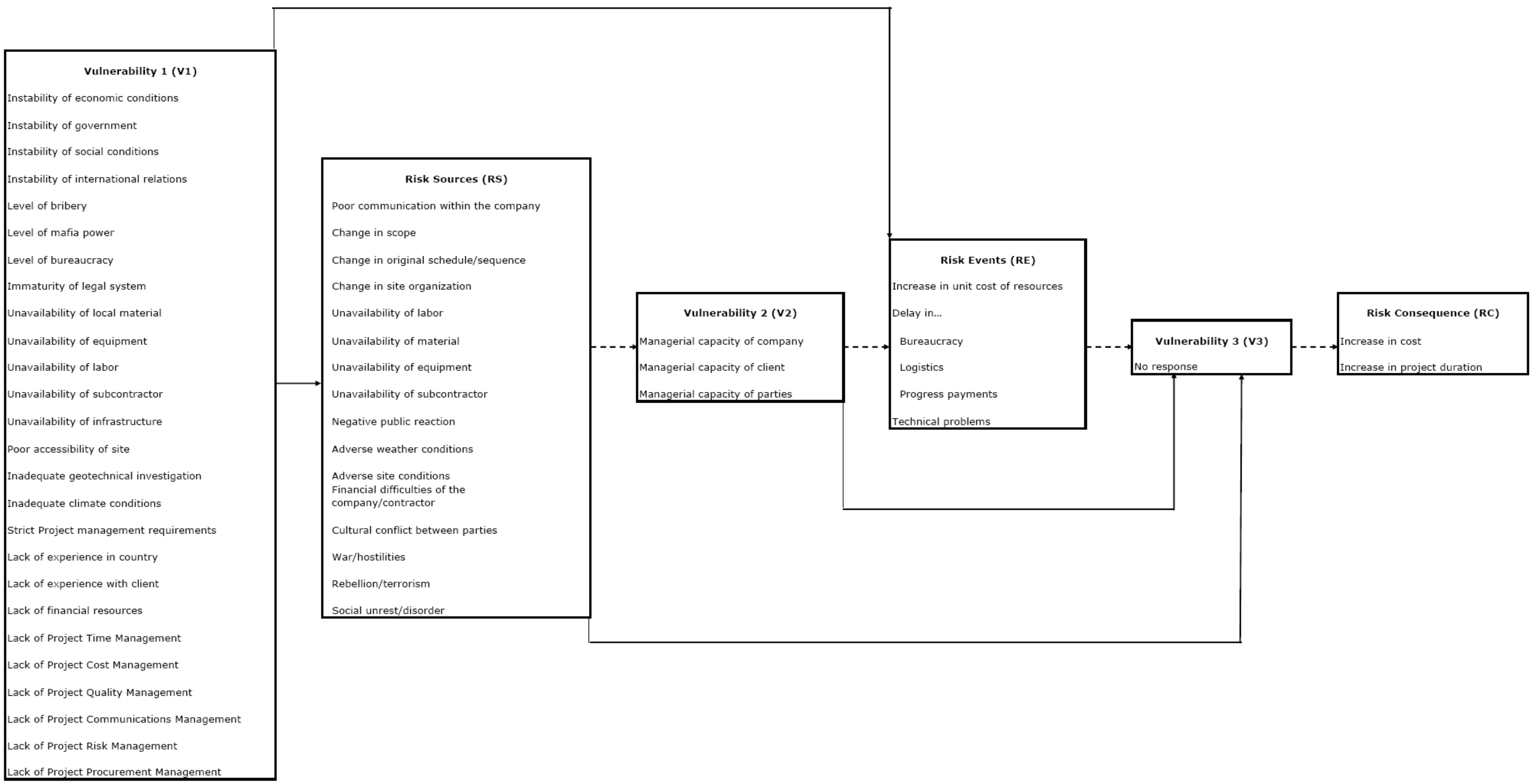

Figure 7: Risk and Vulnerability Paths for Case Study 4

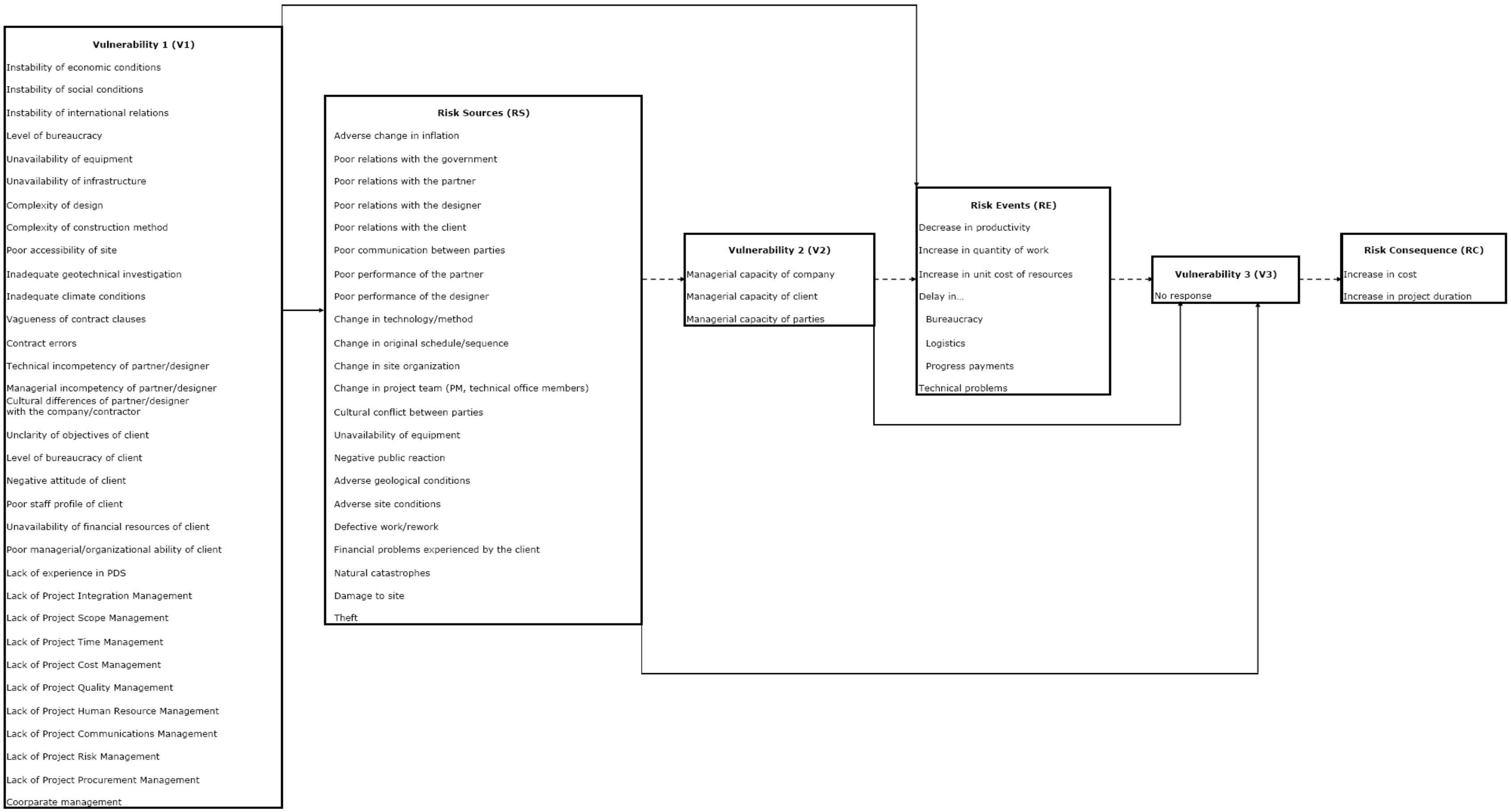

Figure 8: Risk and Vulnerability Paths for Case Study 5

4.3. Lessons Learned from Case Studies

The sample risk and vulnerability paths obtained from five real case studies revealed that the current framework should be modified. Case studies show that:

- Some of the risk and vulnerability parameters obtained from the literature survey should be adapted to the structure or considered under a broader category regarding to the real construction industry. As an example of this adaptation, change in international relations was moved from RS group to V1 group. Similarly, conflict between parties was extracted from RE as it will take place after the generation of risk consequences.
- Some of the risk and vulnerability parameters should be written in a different manner to prevent misunderstanding. For instance, change in government's policy and government's attitude to foreign investors are modified as change in relations with the government. Similarly, design maturity is changed into incomplete design, while site conditions is written as poor accessibility of site.
- The place of some of the risk and vulnerability parameters on the risk and vulnerability framework shown on Figure 3 of Chapter 3 should be changed according to the information acquired from the interviews. For example, contract clauses under the V3 group are moved under the V1 group as the contract clauses are mentioned as a reason of RS by the interviewees.
- There should be extra risk and vulnerability parameters in order to get a more reasonable path. As an instance, change in communication between parties, change in original schedule/sequence, change in site organization, and change in project team (PM, technical office members) are added to the risks while unavailability of subcontractor, unavailability of infrastructure, complexity of design, design errors, level of

bureaucracy, level of bribery, and level of mafia power are added to the vulnerabilities.

- The risk and vulnerability parameters do not need to follow all of the parts of the path V1-RC in order. For example, a path starting from V1 and RS need not to pass through V2 and RE. It can continue with V3 and RC directly. The varying paths are decided to be illustrated by an IDEF0 diagram.
- The relations described in Figure 3 of Chapter 3 are not enough to show the interrelations between parameters. Therefore the additional relationships together with the existing ones should be placed on the IDEF0 diagram.
- All of the parameters except RC should be rated in 1-5 scale in order to obtain more precise results. RC values should be assessed numerically such as in percent (%).
- The sub-(sub) categories of RS, V2, RE, V3 and RC can be omitted.
- RS should be divided into two categories such as "changes" and "unexpected conditions".
- V2 parameters should be modified in order to reflect the manageability of the RS by the company. Moreover, it is needed to show the overall impact of RS after managing the risks. For instance the manageability level of change in inflation should be rated in 1-5 scale and the final impact should be evaluated considering this manageability level.
- V3 should entail the sensitivity of RC due to RE group.
- Impact on the level of client satisfaction and disputes can be eliminated from the RC group. Although they have extensive importance, the level of client satisfaction and disputes should be considered in the forthcoming steps after evaluating the impact of the increase in project cost and duration. This study is mainly concerned with the immediate consequences of the risk and vulnerability paths such as project cost and duration. The long-term consequence can be assessed additionally, however this time,

other factors such as the goals of the company should be thought in the system. In order to simplify the assessment, it is decided to finalize this framework when the final impact on the project cost and duration is acquired.

The case studies are conducted to verify the generic structure that encompasses the risk and vulnerability paths. Considering the outcomes of the effect of real case studies on the current research, the elements of the final risk and vulnerability assessment framework will be presented in the following chapter.

CHAPTER 5

THE FINAL RISK AND VULNERABILITY ASSESSMENT STRUCTURE

5.1. The Final Risk and Vulnerability Assessment Structure

The final risk and vulnerability assessment framework is shown by an IDEF0 diagram in Figure 9. In the figure, two activities are defined as vulnerability assessment (A0) and risk assessment (A1). First point is that data for vulnerability assessment is entered by the project team while for risk assessment this is done by project manager. At the beginning of the model uncertainty about country, project, parties, and company are given to A0 to obtain possibility to cause "changes" (V1). This becomes the input of A1 and allows the evaluation of magnitude of "changes" (R1). Magnitude of "changes" (R1) and manageability of "changes" (V2) are controlled by A0 simultaneously and magnitude of "changes" after managing risks (R1') is evaluated. R1' enters as control to A1 together with potential to occur "unexpected conditions" (R2) and as a result, magnitude of increase/decrease or delay (RE) is obtained. RE is controlled by A0 in order to give impact of RE on project performance (V3). V3 becomes input of A1 and finally, level of cost overrun and/or delay (RC) is estimated by the model.

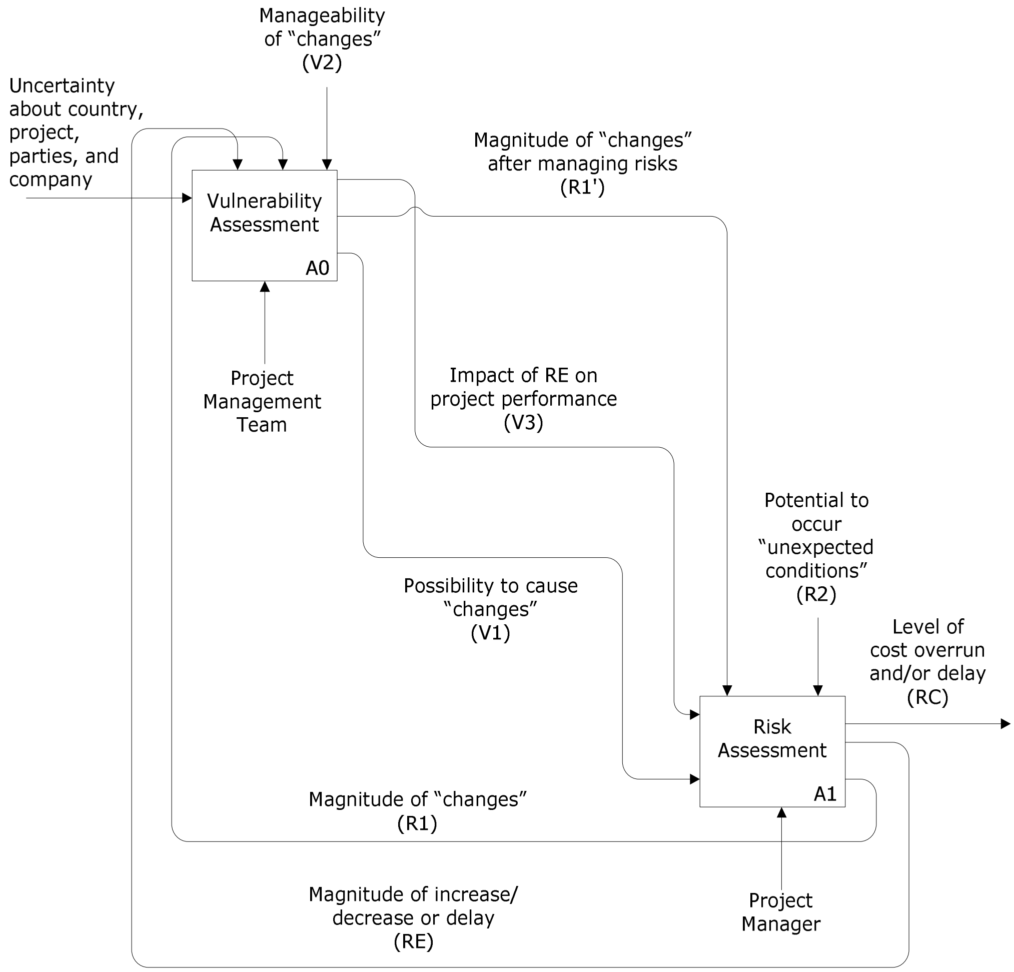

Figure 9: The Final Risk and Vulnerability Assessment Framework

Table 9 presents the final risk and vulnerability factors. Throughout the final parameters, only the ones standing for possibility to cause "changes" (V1) is divided into groups as country, project, parties, and company and sub-groups as economic, political, social, legal, market, design, construction, external, management, contract, and partner in order to increase the ease of intelligibility of the factors. As shown in the table, some of the risk source parameters reflect "changes" related to economical, political, legal, market, technical, company, and party issues while some show "unexpected conditions" like war/hostilities, rebellion/terrorism, and natural catastrophes. V2 factors indicating the manageability level of "changes" in risk sources are developed with the intention of mitigating the effects of R1 that have occurred. In other words, V2 parameters create a transition area that tries to decrease/control the impact on RE caused by R1. RE stands for decrease/increase or delay in various parameters. It comprises the factors occurred as a result of the formation of risk sources. V3 shows the sensitivity which indicates the impact of RE factors on the project performance (cost and duration). Finally, RC shows the variation in overall project cost and duration.

Table 9: The Final Risk and Vulnerability Factors (revised)

Category	Factors		
Vulnerability (V1)	Country	Economic	Instability of economic conditions
		Political	Instability of government
			Instability of international relations
			Level of bureaucracy
			Level of bribery
			Level of mafia power
			Instability of social conditions
		Legal	Immaturity of legal system
			Restrictions for foreign companies
		Market	Unavailability of local material
			Unavailability of equipment
			Unavailability of labor
			Unavailability of subcontractor
			Unavailability of infrastructure
	Project	Design	Complexity of design
			Incomplete design
			Low constructability
			Design errors

Table 9: The Final Risk and Vulnerability Factors (revised) (cont'd)

Category	Factors		
Vulnerability (V1)	Project	Construction	Complexity of construction method
			Poor accessibility of site
			Inadequate geotechnical investigation
			Inadequate climate conditions
		Management	Strict quality management requirements
			Strict environmental management requirements
			Strict Health & Safety management requirements
			Strict Project management requirements
		Contract	Vagueness of contract clauses
			Contract errors
	Parties	Partner	Technical incompetency
			Managerial incompetency
			Lack of financial resources
			Cultural differences with the company/contractor
		Designer	Technical incompetency
			Managerial incompetency
			Lack of financial resources
			Cultural differences with the company/contractor
		Consultant/ Engineer	Technical incompetency
			Managerial incompetency
			Lack of financial resources
			Cultural differences with the company/contractor
		Client	Unclarity of objectives
			Level of bureaucracy
			Negative attitude
			Poor staff profile
			Unavailability of financial resources
			Technical incompetency
			Poor managerial/organizational ability
	Company	Experience	Lack of experience in similar projects
			Lack of experience in country
			Lack of experience in PDS

Table 9: The Final Risk and Vulnerability Factors (revised) (cont'd)

<table>
<tr><th>Category</th><th colspan="3">Factors</th></tr>
<tr><td rowspan="16">Vulnerability (V1)</td><td rowspan="16">Company</td><td rowspan="2">Experience</td><td>Lack of experience with client</td></tr>
<tr><td>Lack of experience with partner</td></tr>
<tr><td rowspan="3">Resources</td><td>Lack of financial resources</td></tr>
<tr><td>Lack of technical resources</td></tr>
<tr><td>Lack of staff</td></tr>
<tr><td rowspan="8">Managerial capability</td><td>Lack of Project Scope Management</td></tr>
<tr><td>Lack of Project Time Management</td></tr>
<tr><td>Lack of Project Cost Management</td></tr>
<tr><td>Lack of Project Quality Management</td></tr>
<tr><td>Lack of Project Human Resource Management</td></tr>
<tr><td>Lack of Project Communications Management</td></tr>
<tr><td>Lack of Project Risk Management</td></tr>
<tr><td>Lack of Project Procurement Management</td></tr>
<tr><td rowspan="21">Risk Sources (R1)</td><td colspan="3">Adverse change in currency rates</td></tr>
<tr><td colspan="3">Adverse change in inflation</td></tr>
<tr><td colspan="3">Adverse change in tax rates</td></tr>
<tr><td colspan="3">Adverse change in laws and regulations</td></tr>
<tr><td colspan="3">Adverse change in relations with the government</td></tr>
<tr><td colspan="3">Adverse change in relations with the partner</td></tr>
<tr><td colspan="3">Adverse change in relations with the engineer</td></tr>
<tr><td colspan="3">Adverse change in relations with the designer</td></tr>
<tr><td colspan="3">Adverse change in relations with the client</td></tr>
<tr><td colspan="3">Adverse change in communication between parties</td></tr>
<tr><td colspan="3">Adverse change in performance of the partner</td></tr>
<tr><td colspan="3">Adverse change in performance of the designer</td></tr>
<tr><td colspan="3">Adverse change in performance of the engineer</td></tr>
<tr><td colspan="3">Adverse change in scope</td></tr>
<tr><td colspan="3">Adverse change in design</td></tr>
<tr><td colspan="3">Adverse change in technology/method</td></tr>
<tr><td colspan="3">Adverse change in client's staff</td></tr>
<tr><td colspan="3">Adverse change in original schedule/sequence</td></tr>
<tr><td colspan="3">Adverse change in site organization</td></tr>
<tr><td colspan="3">Adverse change in project team (PM, technical office members)</td></tr>
<tr><td colspan="3">Adverse change in top management (company)</td></tr>
</table>

Table 9: The Final Risk and Vulnerability Factors (revised) (cont'd)

Category	Factors
Risk Sources (R1)	Adverse change in availability of labor
	Adverse change in availability of material
	Adverse change in availability of equipment
	Adverse change in availability of subcontractor
	Adverse change in public reaction
	Adverse change in attitude of client
	Adverse change in weather conditions
	Adverse change in geological conditions
	Adverse change in site conditions
	Adverse change in work quality/rework
	Adverse change in financial situation of the client
	Adverse change in financial situation of company/contractor
	Adverse change in financial situation of the partner
	Adverse change in performance of contractor/ Inadequacy in fulfilling client's requirements
Risk Sources (R2)	Social unrest/disorder
	War/hostilities
	Rebellion/terrorism
	Natural catastrophes
	Historical findings
	Accidents
	Damage to site
	Theft
	Strikes/labor problems
Vulnerability (V2)	Manageability level of the risk sources
Risk Events (RE)	Decrease in productivity
	Increase in quantity of work
	Decrease in quality of work
	Increase in unit cost of resources
	Delay in…
	Bureaucracy
	Site hand-over
	Logistics
	Progress payments

Table 9: The Final Risk and Vulnerability Factors (revised) (cont'd)

Category	Factors
Vulnerability (V3)	The impact of "Decrease in productivity" on the project cost/duration.
	The impact of "Increase in quantity of work" on the project cost/duration.
	The impact of "Decrease in quality of work" on the project cost/duration.
	The impact of "Increase in unit cost of resources" on the project cost/duration.
	The impact of "Delay in bureaucracy" on the project cost/duration.
	The impact of "Delay in site hand-over" on the project cost/duration.
	The impact of "Delay in logistics" on the project cost/duration.
	The impact of "Delay in progress payments" on the project cost/duration.
Risk Consequence (RC)	Increase in project cost
	Increase in project duration

5.2. Assessment Method

The risk-vulnerability framework is created not only to reveal the relationships between risk and vulnerability parameters but also it will be used to develop a prediction model. Necessary information shall be collected to feed into the model so that it can be used to predict the amount of cost overrun and delay in a project when the vulnerabilities and risk sources are determined. At this part of the thesis, an assessment method will be proposed, the data necessary to develop the prediction model will be defined and the RV assessment questionnaire prepared with the aim of gathering the related data will be presented.

A stepwise procedure for risk and vulnerability assessment is presented below:

Step 1. Assessment of vulnerability: For quantification of level of vulnerability, experts are firstly requested to evaluate the potential of a given list of factors to create risk in international projects. Part-A of the aforementioned questionnaire (given in appendix A) is designed to collect some information about risk creating potential of vulnerability factors. The questions in Part A are not directly related to the current project's properties. They aim to obtain potential of V1 factors to create risks in the international construction market. The potential is rated in 1-5 scale as 1 being very low and 5 being very high. For example if the complexity of design is rated as 4, it means that this factor has a high potential of creating risks when the international construction market is considered. There are a total of 63 factors in this part and they are grouped into 17 categories such as: economic, political, social, legal, market, design, construction, external, management, contract, partner, designer, consultant/engineer, client, company experience, company resources and company managerial capability.

Step 2. Evaluation of level of vulnerability in a given project: In Part B, respondents are asked to refer to a specific project and comment on the level of risk and vulnerability according to what happened in this project. Initially, respondents are requested to evaluate the level of vulnerability in the project by considering the 63 vulnerability factors indicated in the questionnaire using a 1-5 scale. These factors affect the probability of occurrence of risk sources (R1), thus, will be used to predict amount of change in a project.

Step 3. Evaluation of magnitude of "change": Respondents are asked to indicate the magnitude of "change" experienced in a project regarding the potential sources of risk (R1) on a 1-5 scale. Here, there is also a chance that R1 parameters might not have changed in a project and thus, may have a magnitude of 0.

Step 4. Assessment of manageability of risk sources: The manageability stands for V2 as shown in Figure 10. Level of manageability of each "change" (R1) shall be assessed by the respondent considering the response strategies used to minimize/eliminate risk in the project. 1-5 scale is used to evaluate level of manageability regarding each risk.

Step 5. Assessment of the final impact of risk (change) on project cost and duration after it has been managed: Overall effect/impact of R1 factors on the project cost and duration shall be assessed after they are managed. The aim is to find out the final impact/consequence after managing the risk parameters, if applicable. Experts are requested to indicate the final impacts of R1 using a 1-5 scale. In this part, the experts should ignore the risk allocation between parties as it is assumed to take place after the formation of risk events. Moreover the profitability level of the company should be disregarded while entering the impact of change on the project performance. It is the cost and duration of the "project" that should be assessed rather than cost retained by the "company" or delay retained by the "company".

Step 6. Indication of whether uncontrollable risk sources happened or not: It should be indicated by the experts whether any unexpected/uncontrollable risk sources (R2) have occurred or not. If occurred, they should be assigned a rating of 1, otherwise they should be assigned a rating of 0. If one or more of them have arisen, their impact/consequence is questioned on the project performance (cost and duration) on the 1-5 scale.

Step 7. Assessment of magnitude of risk events occurred as a result of risk sources: The magnitude of the risk events are expected to be rated by the experts, if they have happened, using a scale of 1-5. Otherwise, they should be rated as 0. Risk events are mainly about "variation" in risk sensitive parameters or "delay".

Step 8. Assessment of impact of risk events on cost and duration: The final impact of risk events on cost and duration depends on the "sensitivity" of cost and duration to identified risk events. The level of sensitivity is indicated as V3 in Figure 10. In the questionnaire, "impact" of each occurred risk event on both the project cost and duration should be rated to reveal the level of sensitivity. This assessment should also be done using a 1-5 scale.

Step 9. Quantification of cost overrun and delay: The respondents are asked to indicate the change/deviation of the project cost and duration from the original (contract) values. The deviations are supposed to be entered in percentages (%) for both cost and duration.

The data gathered as a result of this 9-step procedure will be used to develop a prediction model. If enough data is collected regarding the international construction projects carried out before, the cause-effect relationships between the inputs and outputs at each step can be examined by statistical methods (such as regression analysis) or artificial intelligence (AI) methodologies (such as case-based reasoning, neural networks etc.). The aim of this study is just to develop the conceptual model and design the data collection method as well as the format of the questionnaire which form the basis of the prediction model, which is the subject of a forthcoming study. The prediction models that should be developed to predict the level of cost overrun and delay are shown in Figures 10-14 below.

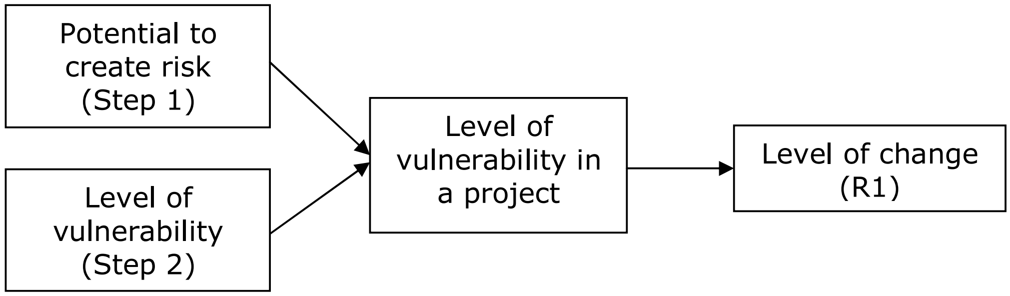

Figure 10: Prediction Model 1

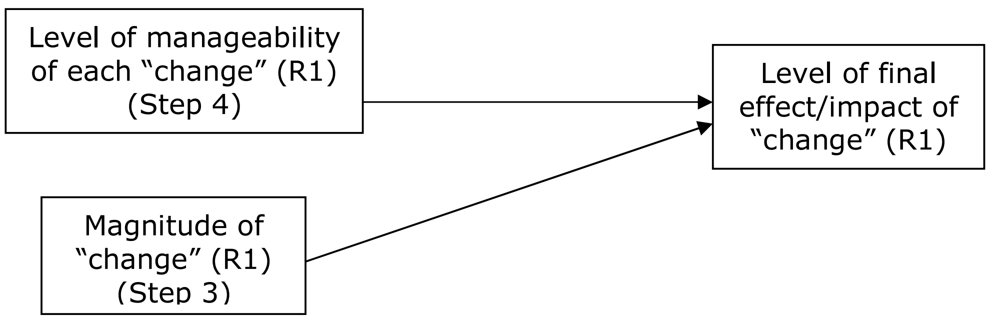

Figure 11: Prediction Model 2

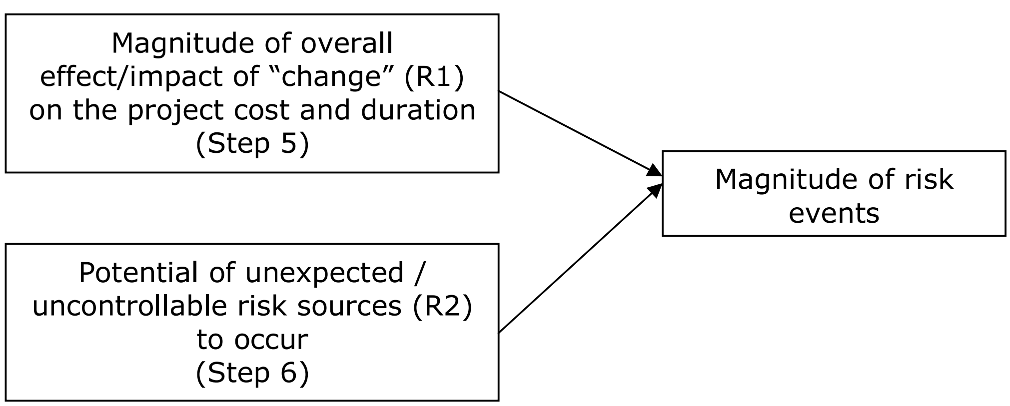

Figure 12: Prediction Model 3

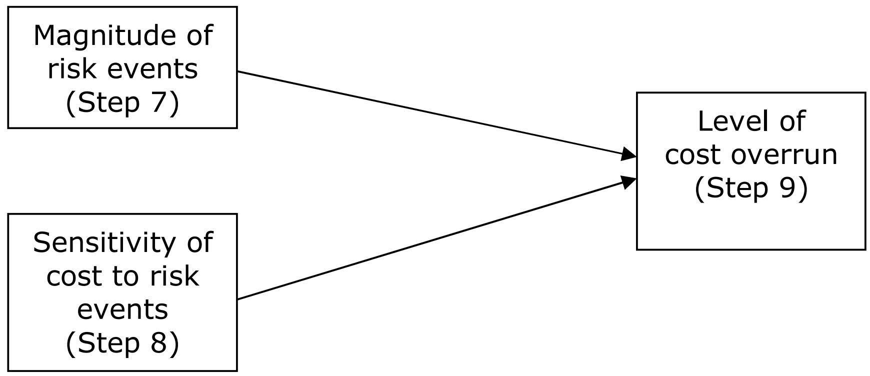

Figure 13: Prediction Model 4

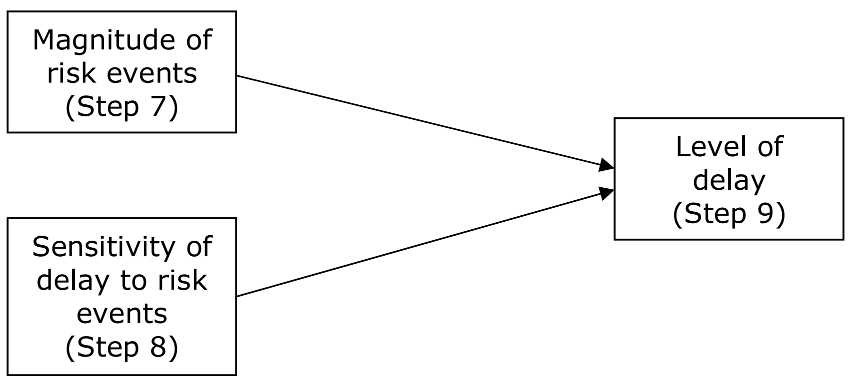

Figure 14: Prediction Model 5

Finally, after the prediction models (statistical or AI) are constructed using the collected data, cost overrun and delay in a project can be automatically calculated when the user enters some information about vulnerabilities (V1, V2 and V3).

A final recommendation about prediction model is that, as the data that is provided by the experts would entail a high degree of subjectivity, they should be treated as fuzzy numbers rather than crisp numbers. Fuzzy membership functions are suggested to be used in the assessment of risk, vulnerability and impact values in order to account for the vagueness and subjectivity in data.

CHAPTER 6

CONCLUSION

When Project Risk Management (PRM) literature is investigated, it is observed that the emphasis is on the quantification of risks. The risk identification and assessment process is of greatest importance as the risk models are constructed based on previously defined risks sources and their interrelations. This process has some bottlenecks as the influence of the various chains of risk events and the capacity of a "system" to react to risk events are not considered simultaneously in the previous studies. Major aim of this thesis is to propose an integrated risk assessment model to overcome this shortcoming in PRM by combining "risk path" and "vulnerability" concepts.

PRM literature includes various studies related to risk identification and assessment. Although "risk path" and "vulnerability" are defined separately, none of the previous researchers tried to combine the effects of both in a single model. As the assessment model may not give adequate and applicable results without taking into account the source-event link and system characteristics, "risk path" and "vulnerability" theories will be integrated into the PRM procedure in the limits of this study.

"Risk path" includes the cause-effect relationships while "vulnerability" stands for the risk carrying and managing capacities of the organization, company and project. The corresponding parameters for risk and vulnerability were defined through a detailed literature survey and engineering judgment. The parameters were grouped by forming Hierarchical Risk-Breakdown Structures (HRBS) for the ease of elimination. Firstly, a preliminary Risk-Vulnerability (RV) assessment framework is constructed based on the factors obtained from the literature. This model showed the vital role of risk paths and vulnerability in clarifying and interrelating risk sources to their consequences that pass through risk events. It was obvious that the definition should be enlarged and verified by a further study of the model by referring to real practices in the construction industry by carrying out interviews with experts. Therefore, interviews were conducted about five real case studies about various types of projects. The following interferences were obtained from the cases:

- Some of the risk and vulnerability parameters obtained from the literature survey should be adapted to the structure or considered under a broader category regarding to the real construction industry.
- Some of the risk and vulnerability parameters should be written in a different manner to prevent misunderstanding. For instance, design maturity is changed into incomplete design, while site conditions is written as poor accessibility of site.
- The place of some of the risk and vulnerability parameters on the preliminary risk and vulnerability framework should be changed according to the information acquired from the interviews. For example, contract clauses under the V3 group are moved under the V1 group as the contract clauses are mentioned as a reason of RS by the interviewees.
- There should be extra risk and vulnerability parameters in order to get a more reasonable path. For instance, change in communication between parties and change in original

schedule/sequence are added to the risks while unavailability of subcontractor and unavailability of infrastructure are added to the vulnerabilities.

- The risk and vulnerability parameters do not need to follow all of the parts of the path V1-RC in order. For example, a path starting from V1 and RS need not to pass through V2 and RE. It can continue with V3 and RC directly.
- The relations described in the preliminary model should be enlarged to show all of the interrelations between parameters. Therefore four additional relations are decided to be defined between V1 and RE, R1 and V3, R2 and V3, and V2 and V3.
- All of the parameters except RC should be rated in 1-5 scale in order to obtain more precise results.
- RC values should be assessed numerically such as in percent (%).
- The sub-(sub) categories of RS, V2, RE, V3 and RC can be omitted.
- RS should be considered as "changes" and "unexpected conditions".
- The model should include the preliminary magnitude of RS and the overall effect/impact of RS after managing the risks. Thus vulnerability parameters should consist of the manageability of RS by thinking of the company point of view.
- Vulnerability parameters should be modified in order to reflect the risk response strategies of the company.
- The immediate consequences such as the ones on the project performance (cost and duration) are decided to be shown in the final risk and vulnerability assessment framework.

The interferences summarize the properties that a generic risk and vulnerability assessment framework should have. Under the light of the information acquired from the interviews, the preliminary model is modified and the final assessment structure is created. It is concluded that the final risk and vulnerability assessment structure is required to have:

- *A path structure:* The path structure should include risk and vulnerability factors that affect the performance on the overall cost and duration of the international construction projects. Although risk and vulnerability parameters need not to follow one another in order, the interrelations between them should be presented by the help of risk and vulnerability network structure.
- *Three types of vulnerability parameters:* The first type should not only have a potential to create risk sources but also affect the magnitudes of risk factors. The second group should stand for the manageability of "changes" in risk sources. The third one should show the impact of each occurred risk event on the project performance (cost and duration).
- *Three kinds of risks:* These are risk sources, events and consequences. First of all, risk sources should be grouped into "changes" and "unexpected conditions" according to their controllability. Secondly, risk events should be regarded as increase/decrease and delays in several items. Finally, risk consequences should reflect the final change in the project performance (cost and duration) considering the original values given in the contract.
- *Two types of relations between risk and vulnerability parameters as direct and indirect:* Direct relationship should show the impacts on risk parameters such as risk sources, events and consequences. Indirect impact should imply the dependence of factors through vulnerability. That is, direct relations should have an influence on the occurrence or magnitude of the risk parameters while indirect ones should show the same effect by passing through the vulnerabilities.

Considering these requirements, the final risk and vulnerability assessment structure is constructed for the international construction industry. For this purpose a risk and vulnerability questionnaire is developed which includes questions that require the ratings of risk and vulnerability parameters in 1-5 scale from very low to very high. The questionnaire aims to collect data about the present paths in the international construction market and form the basis of the prediction model, which is the subject of a forthcoming study.

The collection of data for the analysis of the framework is recommended to be performed based on the risk and vulnerability questionnaire created as a result of this study. As the main concern of this study is to create a model to define and organize risk and vulnerability factors together with their interrelations and design the data collection method as well as the format of the questionnaire, the accomplishment of the data collection and development of the prediction models are not in the scope of this thesis. However, it should be noted that the data for the pre-defined risk and vulnerability parameters need to be collected and analyzed in the forthcoming studies so that the level of cost overrun and delay in a project can be predicted considering different scenarios that may emerge as a result of risk and vulnerability factors.

It is suggested that the cause-effect relationships between the inputs and outputs at each step of the prediction models can be examined by statistical methods (such as regression analysis) or artificial intelligence (AI) methodologies (such as case-based reasoning, neural networks etc.). These methods will enable the construction of prediction models and integration of the collected data into the models in order to get quantitative results on the project cost and duration automatically. Moreover, as the data that is provided by the experts would entail a high degree of subjectivity, they should be treated as fuzzy numbers rather than crisp numbers. Fuzzy set theory is advised to be used in the assessment of risk, vulnerability and impact values in order to account for the vagueness and subjectivity in data. However, it should be noted that, one of the assumptions of this study is that, enough data can be collected to construct the prediction models and the input-output variables of the models are adequately defined so that prediction models give reliable results. After the data is collected and different iterations are made to find the best model, it may appear that some of the variables are redundant, some new variables should be added so on.

To sum up, a risk-vulnerability breakdown structure is proposed in this research in order that a realistic model that take into account of both vulnerability and risk factors as well as their interrelations can be constructed. The proposed structure results in a common language and an ontology for formalization of risk identification and assessment process in international construction projects. The major idea of this research is that, risk-vulnerability paths should be considered during risk modeling in order to create various scenarios and evaluate the probability and impact of risk and vulnerability items on the overall project performance (cost and duration) by the help of a decision-maker. In the forthcoming steps, prediction models will be constructed by collecting the relevant data using the RV questionnaire depicted in this study and final impacts on each party (cost overrun and delay retained by each party) will be quantified considering their differing objective functions, risk perceptions, risk allocation schemes in the contract and negotiation processes between the project participants on a multi-agent platform.

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APPENDIX A

A SAMPLE OF THE RISK AND VULNERABILITY QUESTIONNAIRE

Project Risk Management (PRM) is a combined process of identifying, assessing and mitigating risks. Although, risk assessment is a vital part of PRM, there are some methodological problems regarding quantification of risks. Previous studies about risk assessment do not take into account of vulnerability factors and source-event relations. In this research, vulnerability factors stand for country and project characteristics while source-effect relations show the causal interrelation between risk and vulnerability parameters.

This questionnaire is prepared to collect necessary data to produce a tool that can be used to predict cost overrun and delay in construction projects by considering the risk and vulnerability factors. Questions in Part-A are asked to obtain general information about vulnerability factors in international construction projects. In Part-B, project specific information is required for the rating of risk and vulnerability factors.

Please start the questionnaire by entering some general information about your project:

Table 10: General Information about Sample Projects

Project Location (Country)	
Project Type	
Project Delivery System	
Project Duration	
Project Size	
Payment Type	
Type of Partnership	

PART-A

Following are some vulnerability factors that have a potential to create risks. Please rate the potential of these factors to create risks in the international construction environment:

No	Groups	Items	1	2	3	4	5	No	Groups	Items	1	2	3	4	5
1	Economic	Instability of economic conditions						33	Designer	Technical incompetency					
2	Political	Instability of government						34		Managerial incompetency					
3		Instability of international relations						35		Lack of financial resources					
4		Level of bureaucracy						36		Cultural differences with the company/contractor					
5	Social	Level of bribery						37	Consultant/ Engineer	Technical incompetency					
6		Level of mafia power						38		Managerial incompetency					
7		Instability of social conditions						39		Lack of financial resources					
8	Legal	Immaturity of legal system						40		Cultural differences with the company/contractor					
9		Restrictions for foreign companies						41	Client	Unclarity of objectives					
10	Market	Unavailability of local material						42		Level of bureaucracy					
11		Unavailability of equipment						43		Negative attitude					
12		Unavailability of labor						44		Poor staff profile					
13		Unavailability of subcontractor						45		Unavailability of financial resources					
14		Unavailability of infrastructure						46		Technical incompetency					
15	Design	Complexity of design						47		Poor managerial/organizational ability					
16		Incomplete design						48	Company Experience	Lack of experience in similar projects					
17		Low constructability						49		Lack of experience in country					
18		Design errors						50		Lack of experience in PDS					
19	Construction	Complexity of construction method						51		Lack of experience with client					
20		Poor accessibility of site						52		Lack of experience with partner					
21	External	Inadequate geotechnical investigation						53	Company Resources	Lack of financial resources					
22		Inadequate climate conditions						54		Lack of technical resources					
23	Management	Strict quality management requirements						55		Lack of staff					
24		Strict enviromental management requirements						56	Company Managerial Capability	Lack of Project Scope Management					
25		Strict Health&Safety management requirements						57		Lack of Project Time Management					
26		Strict Project management requirements						58		Lack of Project Cost Management					
27	Contract	Vagueness of contract clauses						59		Lack of Project Quality Management					
28		Contract errors						60		Lack of Project Human Resource Management					
29	Partner	Technical incompetency						61		Lack of Project Communications Management					
30		Managerial incompetency						62		Lack of Project Risk Management					
31		Lack of financial resources						63		Lack of Project Procurement Management					
32		Cultural differences with the company/contractor													

LEGEND	
1	Very Low
2	Low
3	Medium
4	High
5	Very High

Figure 15: RV Questionnaire Page 2

PART-B

A. Please rate the magnitude of the following items considering the preliminary stage of your project:

No	Groups	Items	1	2	3	4	5	No	Groups	Items	1	2	3	4	5
1	Economic	Instability of economic conditions						33	Designer	Technical incompetency					
2	Political	Instability of government						34		Managerial incompetency					
3		Instability of international relations						35		Lack of financial resources					
4		Level of bureaucracy						36		Cultural differences with the company/contractor					
5	Social	Level of bribery						37	Consultant/ Engineer	Technical incompetency					
6		Level of mafia power						38		Managerial incompetency					
7		Instability of social conditions						39		Lack of financial resources					
8	Legal	Immaturity of legal system						40		Cultural differences with the company/contractor					
9		Restrictions for foreign companies						41	Client	Unclarity of objectives					
10	Market	Unavailability of local material						42		Level of bureaucracy					
11		Unavailability of equipment						43		Negative attitude					
12		Unavailability of labor						44		Poor staff profile					
13		Unavailability of subcontractor						45		Unavailability of financial resources					
14		Unavailability of infrastructure						46		Technical incompetency					
15	Design	Complexity of design						47		Poor managerial/organizational ability					
16		Incomplete design						48	Company Experience	Lack of experience in similar projects					
17		Low constructability						49		Lack of experience in country					
18		Design errors						50		Lack of experience in PDS					
19	Construction	Complexity of construction method						51		Lack of experience with client					
20		Poor accessibility of site						52		Lack of experience with partner					
21	External	Inadequate geotechnical investigation						53	Company Resources	Lack of financial resources					
22		Inadequate climate conditions						54		Lack of technical resources					
23	Management	Strict quality management requirements						55		Lack of staff					
24		Strict enviromental management requirements						56	Company Managerial Capability	Lack of Project Scope Management					
25		Strict Health&Safety management requirements						57		Lack of Project Time Management					
26		Strict Project management requirements						58		Lack of Project Cost Management					
27	Contract	Vagueness of contract clauses						59		Lack of Project Quality Management					
28		Contract errors						60		Lack of Project Human Resource Management					
29	Partner	Technical incompetency						61		Lack of Project Communications Management					
30		Managerial incompetency						62		Lack of Project Risk Management					
31		Lack of financial resources						63		Lack of Project Procurement Management					
32		Cultural differences with the company/contractor													

LEGEND	
1	Very Low
2	Low
3	Medium
4	High
5	Very High

Figure 16: RV Questionnaire Page 3

B. Please indicate whether there is any adverse change in the initial conditions. If yes, please rate <u>the magnitude of change</u> (deviation from the expected values).							**C. Please indicate the manageability level of the occured risks?**						**D. Please rate the overall impact/consequence of the change on the project performance (cost and duration) after you managed the risks. Please <u>do not</u> consider the risk allocation between parties and profitability level of your company.**					
Risk Factors	No (0)	1	2	3	4	5	0	1	2	3	4	5	0	1	2	3	4	5
Adverse change in currency rates																		
Adverse change in inflation																		
Adverse change in tax rates																		
Adverse change in laws and regulations																		
Adverse change in relations with the government																		
Adverse change in relations with the partner																		
Adverse change in relations with the engineer																		
Adverse change in relations with the designer																		
Adverse change in relations with the client																		
Adverse change in communication between parties																		
Adverse change in performance of the partner																		
Adverse change in performance of the designer																		
Adverse change in performance of the engineer																		
Adverse change in scope																		
Adverse change in design																		
Adverse change in technology/method																		
Adverse change in client's staff																		
Adverse change in original schedule/sequence																		
Adverse change in site organization																		
Adverse change in project team (PM, technical office members)																		
Adverse change in top management (company)																		
Adverse change in availability of labor																		
Adverse change in availability of material																		
Adverse change in availability of equipment																		
Adverse change in availability of subcontractor																		
Adverse change in public reaction																		
Adverse change in atitude of client																		
Adverse change in weather conditions																		
Adverse change in geological conditions																		
Adverse change in site conditions																		
Adverse change in work quality/rework																		
Adverse change in financial situation of the client																		
Adverse change in financial situation of company/contractor																		
Adverse change in financial situation of the partner																		
Adverse change in performance of contractor /Inadequecy in fullfilling client's requirements																		

LEGEND	
1	Very Low
2	Low
3	Medium
4	High
5	Very High

Figure 17: RV Questionnaire Page 4

E. Please indicate whether any one of the following unexpected items occured or not.		**F. Please rate the overall impact/consequence of the unexpected event on the project performance (cost and duration). Please do not consider the risk allocation between parties and profitability level of your company.**					
Risk Factors	Yes/No	0	1	2	3	4	5
Social unrest/disorder							
War/hostilities							
Rebellion/terrorism							
Natural catastrophes							
Historical findings							
Accidents							
Damage to site							
Theft							
Strikes/labor problems							

G. Please indicate the "magnitude of the risk events" occurred as a result of risk factors.							**H. Please rate the "impact of the risk event" on project cost.**					**I. Please rate the "impact of the risk event" on project duration.**				
Risk Events	N/A	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Decrease in productivity																
Increase in quantity of work																
Decrease in quality of work																
Increase in unit cost of resources																
Delay in...																
Bureaucracy																
Site hand-over																
Logistics																
Progress payments																

J. Please indicate the change in the project cost and duration (considering the original values given in the contract):	
Cost (%)	Duration (%)

LEGEND	
1	Very Low
2	Low
3	Medium
4	High
5	Very High

Figure 18: RV Questionnaire Page 5