DEVELOPMENT OF A KNOWLEDGE-BASED RISK MAPPING TOOL FOR INTERNATIONAL CONSTRUCTION PROJECTS

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ABSTRACT

DEVELOPMENT OF A KNOWLEDGE-BASED RISK MAPPING TOOL FOR INTERNATIONAL CONSTRUCTION PROJECTS

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Due to its high-risk nature, international construction projects are more vulnerable to adverse changes in project environment and company objectives. To achieve successful project outcomes, early provision of risks has a vital place in managing construction projects. Within the literature, several risk assessment methodologies have been offered to simulate probable consequences of risks. The majority of the proposed methodologies are limited in reflection of real project conditions as they require probabilistic measures or rely on solely intuition and experience of decision makers. In this study, it is argued that an additional assistance is needed for decision-makers when they are assessing magnitudes of risks under different project and country conditions. The purpose of this study is to develop a knowledge-based risk mapping tool for international construction projects using an ontology that relates risk and vulnerability to cost overrun and a novel risk-vulnerability assessment methodology. The tool incorporates a ‘lessons learned database’ that utilizes learning from previous projects in order to assist decision-makers when quantifying the risk-related variables. The database is expected to aid decision-makers by retrieving and making use of the knowledge of previous projects that have been captured, codified, and stored within the database previously. In addition, to guide decision-makers by giving better understanding of the risk variables, attributes of the risk-related variables are identified that lists probable triggering events for the occurrence of the relevant variables. The tool has also been tested on a real construction project as well as its usability has been ensured by conducting some usability tests.

Keywords: Risk Management, Lessons Learned Database, Risk Map, International Construction Projects

ÖZ

ULUSLARARASI İNŞAAT PROJELERİ İÇİN BİLGİ-TABANLI RİSK HARİTALAMA ARACININ GELİŞTİRİLMESİ

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Uluslararası inşaat projeleri, yüksek risk doğasından ötürü proje hedeflerindeki olumsuz değişimlere karşı daha kırılgandır. Başarılı proje çıktıları elde edebilmek için, risklerin erken gözlemlenmesi inşaat projelerinin yönetiminde önemli bir yere sahiptir. Literatürde, çeşitli risk değerlendirme metodları, risklerin muhtemel sonuçlarını öngörmek için önerilmiştir. Önerilen yöntemlerin bir çoğu, olasılık değerleri gerektirmesi veya sadece karar vericilerin sezgi ve tecrübesine dayanması nedeniyle gerçek proje koşullarının yansıtılmasında sınırlı kalmıştır. Bu çalışmada, karar vericilerin risklerin olası büyüklüklerini belirlerken, ek bir yardıma ihtiyaçları olduğu ileri sürülmüştür. Bu çalışmanın amacı, maliyet artışı ile bağlı olan risk ve kırılganlık ontolojisini ve yeni bir risk-kırılganlık değerlerdirme metodunu kullanarak, uluslararası inşaat projeleri için bir bilgi-tabanlı risk haritalama aracı geliştirmektir. Risklerin büyüklüklerinin belirlenmesinde karar vericilere yardımcı olmak amacıyla, geçmiş projelerinden elde edilen bilgilerin kullanımını sağlayan bir 'bilgi-tabanı' geliştirilmiştir. Bilgi-tabanının, önceden elde edilmiş, kodlanmış ve saklanmış proje bilgilerini, geri çağrılmasını ve kullanılmasını sağlayarak karar vericilere yardımcı olması beklenmektedir. Buna ek olarak, kırılganlık kaynaklarının daha iyi anlaşılmasını sağlayarak karar vericilere rehberlikte bulunması için, bu kaynakların oluşmasını tetikleyen olası olayları listeleyen altnedenler belirlenmiştir. Risk haritalama aracı, gerçek bir inşaat projesinde test edilmiş ve bazı kullanılabilirlik testleri ile araç kullanılabilirliği doğrulanmıştır.

Anahtar Kelimeler: Risk Yönetimi, Bilgi-Tabanı, Risk Haritası, Uluslararası İnşaat Projeleri

To my beloved family...

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LIST OF ABBREVIATIONS

A	Attribute
AC	Adverse Change
AHP	Analytical Hierarchy Process
AR	Attribute Analysis
HCI	Human Computer Interaction
ICRAM	International Construction Risk Assessment Model
ISO	International Organization for Standardization
IT	Information Technologies
KM	Knowledge Management
LL	Lessons Learned
METU	Middle East Technical University
ODE	Ontology-Based Software Engineering Environment
P	Participant
PFE	Partner Firm Experts
PMBoK	Project Management Book of Knowledge
RC	Risk Consequence
RE	Risk Event
RS 1	Risk Source Group 1
RS2	Risk Source Group 2
SEM	Structural Equation Modeling
TCA	Turkish Contractors Association
TSE	Turkish Standards Institution
V	Vulnerability
V1	Vulnerability Group 1
V2	Vulnerability Group 2
V3	Vulnerability Group 3
VS	Vulnerability Source

CHAPTER 1

INTRODUCTION

The time, cost and quality goals in construction projects are hardly achieved due to their complex and fragmented nature, which involves high degree of risks and uncertainties from beginning to the end of projects (Akintoye and Macleod, 1997; Mustafa and Al-Bahar, 1991). Unique features of the construction projects, such as long project durations, complicated construction methods, and dynamic organization structures, subject the construction industry to more risks while compared with other industries (Flanagan and Norman, 1993; Akintoye and MacLeod, 1997; Smith, 1999; Shen et al., 2001).

Apart from the common risks of construction projects that emerge from their nature, internationalization of construction industry resulted in a more complex web of project environment that evolves additional risks to the global projects. While compared with domestic projects, international construction projects are more vulnerable to confront diverse risk factors that affect the cost performance of these projects (Bing and Tiong, 1999; del Cano and de la Cruz, 2002; Chan and Tse, 2003, Javernick-Will and Levitt, 2010). Thus, accompanying a more extensive range of risks and complexities emerged from dynamic interrelations among country and project specific factors as well as involvement of diverse participants, assigns a high value to the course of risk management for international construction projects.

Risk management in construction industry refers to the systematic and iterative process of identifying of risk, assessing quantitatively and/or qualitatively the impacts of risks on project objectives and finally, developing measures and strategies to mitigate with the consequences of risks on project outcomes. Within literature, several authors emphasized the role of risk management practices in enhancing the effectiveness of performance of construction practitioners as well as in achieving successful and desirable project outcomes. An overwhelming amount of studies has been conducted in order to contribute risk management literature by developing risk identification and assessment techniques and tools. On the other hand, the effective use of these techniques has been plagued with various bottlenecks that hinder these techniques from simulation of real applications.

In majority of the proposed methods, risk checklists and risk breakdown structures are introduced to identify potential risks of a project, which in turn lead to risks to be assessed individually. On the other hand, several authors highlighted the importance of consideration of interdependencies among risk-related factors and argued that rather than individual risk factors, risks should be assessed considering their causalities to achieve better simulation of project conditions. Some authors suggested using cause-effect diagrams, risk paths, and risk maps with the aim of visualization of interdependencies among risks. However, these attempts do not provide interactions among risk paths and demonstrate an overall risk map structure that covers risk paths generated from cause-effect relationships of risks.

In addition, most researchers have been studied quantitative risk management techniques such as are Sensitivity Analysis, Monte Carlo Simulation, Decision Tree Analysis, Subjective Probability, Fuzzy Risk Rating (Perry and Hayes, 1985; Akintoye and Macleod, 1997; Zeng et al., 2007). On the other hand, some common drawbacks limit the applicability of these techniques. These drawbacks can be summarized as, “the time involvement”, (Kangari and Riggs, 1989; Leung and Chuah, 2008), “difficulty in obtaining probabilistic inputs” (Zeng et al., 2007; Kangari and Riggs, 1989, Choi and Mahadevan, 2008, Leung and Chuah, 2008), and “human/organizational resistance” (Thevendran and Mawdesley, 2004, Leung and Chuah, 2008).

Furthermore, some other authors (i.e. Perry and Hayes, 1985; Mustafa and Al-Bahar, 1991; Akintoye and Macleod, 1997) claimed that, due to unique characteristic of construction projects, there is usually insufficient objective data to assess probability of occurrence of risk consequences; therefore decision-makers rely on intuition and judgment which brings subjectivity in some extents. Various authors argued that, knowledge systems are necessary to facilitate learning from previous projects and enhance risk assessment practices by minimizing subjectivity evolved in assessment outcomes.

In this research, it is argued that a risk assessment methodology that takes into account of interdependencies between individual risk factors as well as vulnerability factors should be utilized for realistic prediction of project outcomes. Within the context of this study, it is aimed to develop a risk mapping tool for international construction projects using an ontology that relates risk and vulnerability to cost overrun and a novel risk-vulnerability assessment methodology. The ontology that relates risk and vulnerability factors to cost overrun was developed and the risk map structure that patterns interrelated risk factors was designed in the initial stages of the project. Configuration of the risk map is based on the hierarchical structure and interdependency coefficients of risk-related factors found by using Structural Equation Modeling (SEM) in the previous stages of the research project.

As a further attempt, in order to assist decision-makers when quantifying the risk-related variables, a 'lessons learned database' has been incorporated that utilizes learning from previous projects. The database is expected to aid decision-makers by retrieving and making use of the knowledge of previous projects that have been captured, codified, and stored within the database previously. The database can further be used to improve organizational learning through the implementation of an organizational risk memory. In order to demonstrate how such a database can be utilized in development of an organizational risk memory and be used in forthcoming projects, a prototype database is developed by capturing the know-how experience of construction experts. In addition, to guide decision-makers by giving better understanding of given risk variables, vulnerability source attributes are identified that lists probable triggering events for the occurrence of the relevant vulnerability sources.

This thesis presents the findings of a two-year research project entitled as "Development of a Knowledge-Based Risk Mapping Tool for International Construction Projects". The project was sponsored by the Ministry of Science, Industry, and Technology and carried out in collaboration with a partner construction company. The partner firm was established in August 2001 with the aim of incorporating project management and IT sector to develop project management models and tools. The firm facilitates project management consultancy for both Turkish and international construction projects with the experience of firm staff that had carried out international projects with leading Turkish construction firms. Partner firm experts contributed to the study by structuring the objectives of this study as well as reflecting their experiences within the case study sessions. The focus of these case studies was to identify two items: 1) applicability of vulnerability source attributes 2) collection of risk event histories that will be used in the development of a prototype lessons learned database.

Within the context of this thesis, Chapter 2 is organized under two sections. Firstly, risk and risk management concepts, previous risk-based approaches, as well as problem determination regarding current literature, are overviewed. In the second part of the Chapter 2, the research objective of this thesis is introduced along with the interviews conducted with partner firm experts. As concluding remarks of this chapter, the risk-vulnerability ontology, the risk map structure, and the risk assessment methodology that constitutes the foundation of the risk mapping tool, is briefly introduced. Chapter 3 introduces the concept of attributes; previous studies on attributes identification and the methodology facilitated in this study to develop vulnerability source attributes are introduced. Chapter 4 introduces the research methodology for the development of lessons learned database by firstly defining the concept of knowledge management and its importance for construction industry. Previous studies on learning-based management approaches are also overviewed along with the reasons why learning mechanisms should be facilitated and why knowledge should be captured within an organization. Chapter 5 introduces the risk mapping tool by explaining fundamentals of the tool, tool architecture, functions of the tool and its expected benefits. The process model of the risk mapping tool is also given in this section. Chapter 6 describes the usability testing conducted to evaluate overall usability and effectiveness of the risk mapping tool. Firstly, existing literature relating usability testing is overviewed, methodology for the usability testing is introduced, and findings of these tests are given in this section. Chapter 7 presents the application of the risk mapping tool into a real construction project. Both vulnerability sources attributes and lessons learned database, are utilized by the company expert and detailed discussions regarding these approaches are given in this section. Finally, Chapter 8 concludes the thesis by summarizing the research methodologies and findings as well as presenting research shortcomings.

In addition to the main text, this thesis also includes three appendices, Appendix A, Appendix B, and Appendix C. Appendix A covers the list of attributes and their brief descriptions. Appendix B contains the collected and reviewed past project cases that were used in the development of the lessons learned database. Appendix C covers a list of questionnaires utilized in the usability testing process.

CHAPTER 2

RESEARCH BACKGROUND

This chapter presents the background of the existing research through twelve main sections. First five sections, introduces the concept of risk and risk management, defines importance, and challenges of risk management, and overviews the existing literature on risk identification and assessment approaches. In the sixth chapter, research objectives of this study are introduced along with the major drawbacks of the current risk-based approaches as well as the discussions held with the partner firm experts. Through section seven to twelve, findings of the previous studies; risk-vulnerability ontology, risk assessment methodology and risk map structure, are presented.

2.1. Definition of Risk

Risk is an inherent variable in the construction lifecycle (Akintoye and MacLeod, 1997). Risk can be a threat to project accomplishment in the case of final impact of risk on project is uncertain (Barber, 2005). In literature, the word "risk" is used in different meanings with different words such as hazard or uncertainty (Al-Bahar and Crandall, 1990). Kartam and Kartam (2001) defined risk as "the probability of occurrence of some uncertain, unpredictable, and even undesirable event(s) that would change the prospects for the profitability on a given investment." PMBoK (2008) accepted risk as an uncertain event or condition, in the case of its occurrence, has a positive or a negative impact on at least one project objective. Although occurrence of risks can be a benefit or a threat on achievability of project goals, generally studies on risk choose the negative or undesirable changes as risk consequences (Zhang, 2007). In construction industry, risk is generally accepted as the combination of probability of occurrence, the degree of impact (severity) and the exposure of all hazards and events adversely affecting an activity (Jannadi and Almishari, 2003, and Chapman, 2001).

2.2. Definition of Risk Management

PMBoK (2008) incorporated risk management as one of the nine major focuses that has been involved in the course of project management. Risk management was defined in PMBoK (2008) as "the processes concerned with conducting risk management planning, identification, analysis, responses, monitoring, and control on a project." Thevendran and Mawdesley (2004) suggested a holistic definition for risk management and accepted it as a "continuously monitored integrated formal process for defining objectives, identifying sources of uncertainties, analyzing these uncertainties and formulating managerial responses in order to produce an acceptable balance between risk and opportunities." According to Dey (2010), risk management contains maximizing the probability of occurrence and impact of positive events while minimizing probability of occurrence and impact of negative events to project objective. In line with these definitions, construction risk management is accepted as a systematic and continuous process of identifying risks evolved in project environment, assessing their impacts on achievability of project goals, and implementing strategies to manage them. In literature, risk management processes are distinguished into four folds; risk identification, risk analysis, risk response and risk monitoring (Perry and Hayes, 1985; Thevendran and Mawdesley, 2004; Al-Bahar and Crandall, 1990; Akintoye and Macleod, 1997). As a more comprehensive classification, Dey (2010) accepted risk management process in six phases: risk management planning, risk identification, qualitative risk analysis, quantitative risk analysis, risk response planning, risk monitoring, and control.

2.3. Importance of Risk Management for Construction Industry

The aim of risk management in construction industry is to protect assets, reputation and accomplishments of a company by minimizing the loss prior to the risk occur (Bing et al., 1999). Implementation of an effective risk management will enable client to carry out a project within the pre-defined project schedule, within the allocated budget and with the assured quality (Thevendran and Mawdesley, 2004). According to Burchett et al. (1999), developing effective risk management methods is crucial on large and complex projects as they are more vulnerable to delays and cost overruns. According to Smith (1999), an early and effective approach toward risk management is fundamental to ensure project success despite risks might not be eliminated. Although risk management cannot avoid all risks and eliminate cost and schedule overruns, it assist project stakeholders to make rational decisions and implement appropriate mitigation strategies as well as aid them by minimizing possible adverse effects and maximizing level of risk control (Kangari and Riggs, 1989; Mojtahedi et al., 2010).

2.4. Challenges of Risk Management in International Construction

Large size of projects and numerous complicated international considerations make international construction projects more vulnerable to be plagued by uncertainties (Zhi, 1995). According to Perry and Hayes (1985) while compared with domestic construction, international construction accompany a more extensive range of risks as well as risks evolved in international construction have a higher probability of occurrence and an impact. According to Pennings (1994), “differences in economic development, regulatory traditions, and political and social infrastructures all increase the risk involved in foreign expansion”. Previous studies focusing on risk management in international construction projects revealed that, besides the common risks of a domestic project, international projects subjected to external risks such as political, economic, cultural risks (Ling and Hoi, 2006, Han and Diekmann, 2001), unawareness of social conditions, bureaucratic formalities, regulatory framework, governing authority (Wang et al., 2004), lack of familiarity with language, cultural customs and business practices (Kim et al. , 2008). In addition, dynamic and complex interrelations among host country and project specific factors result in increasing cost overruns and time delays (Bing and Tiong, 1999; del Cano and de la Cruz, 2002; Chan and Tse, 2003; Javernick-Will and Levitt, 2010) as well as conflicts among project participants from cultural differences (Ghoshal, 1987, Javernick-Will and Levitt, 2010). Thus, development of “a systematic, comprehensive, and proactive risk management process” is essential when carrying out international construction projects (Eybpoosh, 2010). However, lack of information about host country conditions and the challenge of risk identification in an inexperienced environment, make the course of risk management more complicated and crucial approach especially in precontracting stage that comprises numerous uncertainties (Zhi, 1995). Therefore, special attention should be given to the course of risk management to enhance its benefits as well as to undertake complexities and diverse risk factors when doing business abroad.

2.5. Literature Review on Previous Risk Identification and Assessment Approaches

Risk identification refers to the actions of systematically identifying, classifying, and assessing potential risks associated with a construction project (Al-Bahar and Crandall, 1990) and is included as the initial step in a systematic risk management process (Zou et al. 2007; Akinci and Fischer, 1998). As an intermediary step among risk identification and risk response, risk assessment employs evaluation and assessment of probable impact of risks on project objectives in qualitative and/or quantitative manner (Wang and Liu, 2004). Within literature, several checklists, risk breakdown structures, and risk assessment methodologies have been offered to identify and classify potential risks as well as assess their probable severities on project goals.

Long et al. (2004) investigated major problems associated with the large construction projects in developing countries. Authors grouped these problems under five categories; incompetent designers/contractors, poor estimation and change management, social and technological issues, site related issues and improper techniques and tools. Of the 32 identified risks, Mustafa and Al-Bahar (1991) classified them into six subsets: acts of god, physical, financial, and economic, political and environment, design, and job site-related risks. Based on these risk factors, authors analyzed the riskiness of an international construction process with using Analytical Hierarchy Process (AHP). Morote and Vila (2010) suggested incorporating Fuzzy Set Theory and AHP for risk assessment purposes by claiming that Fuzzy Set Theory can deal with subjective judgment in an effective way and AHP can structure large number of risks in risk assessment process. Mojtahedi et al. (2010) considered project risk identification and assessment as a Multi-Attribute Group Decision Making (MAGDM) problem that includes both quantitative and qualitative criteria. Authors employed Potential Risk Breakdown Structure (PRBS) and Nominal Group Technique (NGT) to classify and assess project risks. Perry and Hayes (1985) identified 29 primary sources of risks in a construction project and grouped them in accordance with the nature of the risks, physical, environmental, design, logistics, financial, legal, political, construction, and operation. Thevendran and Mawdesley (2004) presented human risk factors of construction projects and carried out a short questionnaire to investigate perception of construction stakeholders of human risk factors as well as present current mitigation practices with these risks. Shen et al. (2001) described and classified risks associated with sino-foreign construction joint ventures in China. Authors facilitated a risk significance index as well as conducted a survey to assess the relative importance among risks. Carr and

Tah (2001) employed a hierarchical risk breakdown structure and a fuzzy risk rating approach to classify and assess external and internal risks of construction projects. The construction risk management system (CRMS) developed by Al-Bahar and Crandall (1990) enable classifying risks with respect to their nature and potential risk outcomes. The system incorporates influence-diagramming technique and utilizes Monte Carlo Simulation for risk analysis and evaluation purposes. Zhi et al. (1995) identified potential risks in international construction projects, classified them into four sub levels; nation/region, construction industry, company and project. Hastak and Shaked (2000) have suggested a risk model entitled as ICRAM-1 model (International Construction Risk Assessment Model) for assessment of probable risk factors in international construction projects. Authors identified 73 tangible and intangible risk factors and classified them into three interrelated risk levels; macro (country), market, and project levels.

In current literature, several researchers have been contributed construction risk management knowledge by focusing on either schedule or cost (Dey, 2010). Several risk-based approaches have been facilitated to identify and assess causes of delay and cost overruns as well as to analyze cost performance of project stakeholders in construction projects. Enshassi et al. (2009) reviewed 110 factors resulting in time and cost overruns in the Gaza Strip, classified them into 12 groups, and evaluated relative importance of these factors from owners, consultants, and contractors' point of view. Azhar et al. (2008) comprehended 42 cost overrun variables in the construction industry of Pakistan, arranged them into three categories, measured the level of importance and impact of each cost overrun factor, and analyzed the current cost overrun scenario of the local construction industry. Chan and Kumaraswamy (1996) identified and analyzed relative importance of previously identified 83 causes of time overruns in construction projects operated in Hong Kong. Abd El-Razek et al. (2008) investigated 32 factors influencing time overruns in building construction projects when operating in Egypt. Yeo (1990) identified causes of cost overruns and proposed an enhanced capital-cost and contingency-estimating system. Aibinu and Odeyinka (2006) assessed the importance of 44 time-overrun factors associated with construction projects that were carried out in Nigeria. Kaming et al. (1997) examined and classified variables causing time and cost overruns in high-rise construction projects in Indonesia. Authors measured their perceived importance and frequency of occurrence of these variables and as a further attempt analyzed the relationships among these variables by facilitating a factor analysis technique. Sambasivan and Soon (2007) addressed causes and effects of delays in Malaysian construction industry. Through a literature survey, authors investigated 10 most important causes of delay from a list of 6 effects of delay and 28 causes of delay. Shane et al. (2009) identified 18 different cost escalation factors of all types of construction projects. Authors classified cost escalation factors as internal and external based on their source. Kim et al. (2008) developed a model to classify international construction projects into five cost performance groups. Authors predicted cost performance in accord with the contractors' initial cost estimate with facilitating Linear Discriminate Analysis through with factor analysis and bootstrap methods. Baloi and Price (2003) identified global risk factors affecting cost performance of international construction projects and grouped them into seven main folds. With exploring and discussing other decision-making techniques handling uncertainty, authors suggested fuzzy decision framework as a viable technique to model, assess, and manage global risk factors. Idrus et al. (2011) developed a model to measure cost contingency of building and infrastructure projects. Model utilizes fuzzy expert system for risk assessment with the aim of accommodating subjective judgments and experiences of contractors.

In addition, in literature it is argued that although risk checklists and risk breakdown structures assist decision-makers in identifying potential risk factors; they "stay at a simple level of details, such as just listing the risks to limit the quantification and prioritization of interrelated risks" (Han et al., 2008) and underemphasize the importance of interdependencies among them (Ward, 1999). On the other hand, identifying risks as individual factors and neglecting the sequences of their occurrence and cause-effect relations will not be a realistic approach (Eybpoosh et al., 2011). Ward (1999) claimed, "individual risk drivers may not be described in sufficient detail to avoid ambiguity and misunderstandings about what risk is being described". Chapman (2001) and Dikmen et al. (2004) argued that, due to underemphasize of risk relationships, even risk sources or consequences can be regarded as a 'risk', which lead to "risk log becoming a confused mixture of risks and their effects." Chapman (2001) claimed that each risk can have one or more causes (sources), therefore in risk identification, it is crucial to distinct risks and their potential effects or consequences.

Within this context, several authors have been attempted to consider risk interdependencies in the course of risk management. Chapman (2001) proposed studying risk relationships by classifying them as, dependent risks in series and independent risks in parallel. He firstly identified risk-related concepts (causes of risks, risks and risk effects) associated with a hypothetical rail infrastructure project and constructed a graphical representation of cause-effect relationships where 14 ‘causes’ generates five ‘risks’ which are resulted in 3 ‘effects’. Zou et al. (2007) concluded that, risks related with project parties (i.e. client, contractor) and the project objectives (i.e. cost, time, quality) are interdependent each other, indeed these interdependencies exit throughout the project lifecycle. Authors presented a diagram in which, the interactions of ‘risks of different project parties’, affecting various project objectives throughout the feasibility, design, construction and operation stages of projects, are illustrated. Ashley and Bonner (1987) utilized influence diagrams to represent interrelationships between macro risks (political source variables) and micro risks (project consequence variables) and their either direct or indirect effect on project cash flow variables (cost of labor, material, overhead costs and project revenues). Akinci and Fischer (1998) used knowledge maps for demonstration of relationships among uncontrollable risk factors (i.e. economic factors, political risk factors, client related factors and subcontractor related factors) and cost overrun variables (i.e. unit cost, estimated quantity, and final unit cost). Carr and Tah (2001) represented the relationships between risk factors (causes of risks), risks (risk events), and their consequences on project performance measures with the use of cause and effect diagrams. Authors demonstrated risk inter-dependencies among risk-related concepts via risk dependency chains, and included in the risk analysis system to “allow for the fact that in practice, risks are not always independent of each other”. The risk management framework developed by Dey (2010), is one of the effort for relating risk map to risk analysis. He proposed to combine AHP and risk map for risk analysis and response development. Although severity (probability x impact) of each individual risk factor can be derived by placing them on the risk map, it is failed to reflect the interdependencies among risk factors and neglects the sequences of their occurrence. To assess the cost overrun risk rating of an international construction project, Dikmen et al. (2007) incorporated influence diagramming and fuzzy risk rating approach for risk identification and risk assessment purposes. Authors used influence diagrams for representation of hierarchical order and interactions of major sources of country and project risks that relates cost overrun. Han et al. (2008) analyzed the causality between risk variables, sorted them as risk sources (causes) and events with respect to their hierarchical order. Authors constructed series of risk paths from its source to event in order to corporate a scenario-based risk checklist. Wang et al. (2004) presented 28 risk factors related with the international construction in developing counties and classified them in accord with the three hierarchy levels: country, market, and project. Authors utilized Alien Eyes’ Risk Model to represent the influence relations among risks belonging to the identified levels.

Moreover, in recent literature, several researchers have been endeavored to develop computer based software systems to enhance the effectiveness of risk management practices. Akintoye and MacLeod (1997) and Abdou et al. (2004) recommended a computer aided simulation tool entitled as Caspar for modeling of interaction of cost, time, resources, and revenue of a construction project throughout the project lifecycle. The tool also has been employed to measure the consequences of risk factors such as variations in market conditions or production rates, delays and changes in inflation rates. Risk assessor model (RAM), computerized by Jannadi and Almishari (2003), is another systematic approach toward the measurement of the degree of risk evolved in a particular construction activity. Authors claimed that, the developed model is “totally menu-driven with a pop-up menu style”, have user-friendly interface and “built in a way that the user does not have to remember steps or formulas”. Touran and Lopez (2006) developed a computer system model to model and to assess the effects of cost escalation factors on large construction projects with utilizing @Risk. The computer model incorporates “the uncertainty and variability of both delay and escalation factors”. Dikmen et al. (2007) proposed a generic risk model that incorporates influence diagramming method for denoting potential cost overrun risks and a fuzzy risk assessment methodology for assessing cost overrun rating of international construction projects. As a further approach, authors developed a computerized company-specific risk assessment tool based on the proposed risk model and the assessment methodology. Authors claimed that one of the potential advantage of the tool is that, it enables development of an organizational risk memory by storing experience in the tool in the form of IF... THEN rules. A Risk Assessment Model (RAM) developed by Fung et al. (2010) is another attempt in computerized-risk assessment approaches that deals with safety management practices of construction industry. The model enable identifying and predicting the current safety risk levels, carrying out a quantitative risk assessment in accord with the historical data on these levels, prioritizing risk levels of different work trades, assessing the occurrence of probability of the accident as well as assisting safety professionals’ to improve the safety performance and behavior within the different work fields. Cost-Schedule Trade-Off Tool developed by Bayraktar et al. (2011) is an MS Excel-based tool and designed to aid “decision makers in selecting the optimal group of techniques to achieve a specific cost-schedule trade-off goal. Carr and Tah (2001) developed a prototype system to corporate all aspects of risk management process through a single user-friendly interface. In order to enable the access of all project and risk information, the system is designed to integrate with “a database management system”, “project planning software” and “a word processor”. Authors also attempted to facilitate case-based reasoning that assist decision support by capturing, re-using, and comparing knowledge. Marzouk et al. (2008) proposed a knowledge-based expert system to evaluate the attributes of engineering-related delay claims. The system comprised of five main components; system input, claim identifier module, claim procedure module, claim analyzer module and system output. The two major expected features of the system were; providing connectivity with other scheduling software, and assisting inexperienced junior engineers in managing engineering-related delay claims.

2.6. Research Objective

In this research, it is claimed that the traditional approaches suffer from real project simulations due to possessing some common shortcomings (i.e. requiring quantitative input data, assessing risks individually, giving subjective assessment outcomes). Thus, a more reliable user-friendly tool should be developed in order to provide construction practitioners, junior engineers and decision makers to facilitate more reliable and applicable risk management approach. Major objectives of this study are investigated through conducting a review on available literature and undertaking interviews with the partner firm experts. From the literature review, major problems that hinder the applicability of current risk management approaches from real applications are identified. Then, requirements and necessities of construction experts when carrying out risk management process are captured. Firstly, the investigated problems regarding the current risk management approaches were introduced and then expert interviews are discussed.

2.6.1 Problem Determination through Literature Survey

Existing studies focusing on risk identification and assessment in construction projects, have mostly failed to reflect real project conditions and have been mostly limited in applicability in real projects due to possessing some common drawbacks:

1) Quantitative techniques (i.e. Sensitivity Analysis, Monte Carlo Simulation) requiring numerical data form the basis of the most of the existing risk analysis models (Carr and Tah, 2001). On the other hand, high quality data should be collected to conduct these quantitative techniques effectively, but such data are hard to obtain or even do not exist in real construction world (Zeng et al., 2007; Kangari and Riggs, 1989; Choi and Mahadevan, 2008). Rather than numerical terms, much of the risk analysis information is expressed as words or sentences in natural language; thereby, quantitative information might not be

available at the time of planning, indeed making precise decisions by decision makers might be impossible (Kangari and Riggs, 1989). In addition, risk management techniques relying on probability and statistics cannot accurately measure the severity of human-related risk factors that involve complexity and uncertainty, and are qualitative in nature (Thevendran and Mawdesley, 2004). Moreover, the imprecision, ill-definedness and vagueness nature of the contractors' decision problems lead construction problems to be subjective and linguistic while quantitative techniques cannot handle subjectivity (Kangari and Riggs, 1989).

2) In recent literature, several authors (i.e. Chapman, 2001; Kim et al., 2009; Ashley and Bonner, 1987; Dikmen et al., 2007) discussed the necessity of consideration of interdependencies among risk factors. Those aforementioned authors made some encouraging efforts for the demonstration of cause-effect relations among risk factors and contributed to the literature by structuring these relations on knowledge maps, influence diagrams, and risk paths. However, mostly they failed to cover interactions among risk paths and demonstrate an overall risk map structure of the generated risk paths. In practice, cause-effect relationships among risk factors lead to "a network form rather than a one-way hierarchical structure" (Fidan et al. 2011). SEM- based model to predict project performance of international construction projects developed by Kim et al. (2009) should be mentioned as one of the most crucial effort in this regard. In addition, the study of Chapman (2001) is another important contribution on examining cause-effect relations among risks, risk paths generated from these relationships and graphical representation of these paths. In this study, it is claimed that, risk paths should be structured in a network form, such as a risk map, to enable the demonstration of interactions among them. Although Dey (2010) suggested a risk map approach combined with the AHP for risk identification and analysis, it is failed to reflect interdependencies among risk factors and neglects the sequences of their occurrence.

3) Since the construction industry is characterized by its uniqueness, there is usually insufficient objective data to assess probability of occurrence of risk consequences. Thereby, decision-makers rely on intuition, judgment, and individual experience, which bring subjectivity in assessment outcomes in some extents (Perry and Hayes, 1985; Mustafa and Al-Bahar, 1991; Akintoye and Macleod, 1997). However, relying on intuition and tested rules of thumb often fails to manage construction risks as the uncertainty and complexity evolved in construction industry has been expanding (Mustafa and Al-Bahar, 1991). Dikmen et al. (2008) explained the major bottleneck in quantifying the magnitudes of risk factors in future projects as; due to lack of recording the circumstances under which the project

outcomes are occurred, the cause effect relations among the risk factors and outcomes cannot be understood. Some other authors (Kartam and Kartam, 2001; Mustafa and Al-Bahar, 1991; Akinci and Fischer, 1998) added that due to dynamic nature of industry, decision makers should improve their assessments by establishing logical, rational, and systematic procedures. Within this context, in existing literature several authors (i.e. Kıvrak et al. 2008; Yeo (1990); Tserng et al., 2009; Dikmen et al.; 2008) suggested that, knowledge gained in the projects needs to be acquired and stored properly in order to be reused in the forthcoming projects. This reveals the necessity of mechanisms to capture and reuse knowledge to facilitate learning from previous projects and to enhance risk assessment process (Kıvrak et al., 2008). Tserng et al. (2009) and Dikmen et al. (2008) suggested the use of lessons learned databases to facilitate learning from risk events and corporate risk memory in which risk information and lessons learned regarding the factors affecting risk consequences of previous projects, are stored.

4) In current literature, several authors have been suggested to employ computer based software systems for the facilitation of risk management actions in a systematic and effective manner. Jannadi and Almishari (2003) suggested the use of computerized tools or models for estimation purposes by claiming that traditional risk assessment methodologies might consume excessive time and even "a lack of data makes it impossible". Leung and Chuah (1998) added that, traditional risk assessment methods suffer from requiring excessive time and efforts, however utilizing computers and software systems can aid to decrease time spent in risk assessment and increase the applicability of risk management approaches. Akintoye and MacLeod (1997) summarized superiorities of computer-based tools over traditional risk assessment methods as; (1) traditional methods carry out assessment in a deterministic way and they fail to cover consecutive nature of construction industry, (2) computer-based tools can deal with dynamic and uncertain environment of construction industry which enable decision-maker to update his/her plans as project progresses. Al-Zarooni and Abdou (2000) claimed that the utilization of information technology (IT) through the development of computer systems would help in "facilitating and widening the use of risk management as a decision making tool in the construction industry".

2.6.2 Problem Determination through Company Interviews

According to Carr and Tah (2001), "a formalized risk management process is still a rarity within many construction organizations" and one of the major problems regarding risk management techniques is their acceptance by construction experts. Although construction time and cost management is perceived as necessary managerial components to achieve project goals, risk management fall behind from these courses and it cannot become an accepted course by construction practitioners.

In this thesis, it is aimed to capture problems that limit the acceptance of risk management techniques by construction practitioners as well as to determine why these techniques are not reliable and effective in real use. Within this context, interviews are taken place with the partner firm experts in order to discuss shortcomings of the current risk management systems and tools, which suffer these tools from practical application. As a further attempt, the knowledge gained through interviews are also be facilitated in defining fundamentals and functions of the risk mapping tool that should be designed in order to satisfy the needs of industry as well as to investigate knowledge required for the development of such a tool.

Prior to the development of the risk-mapping tool, firstly the risk-vulnerability ontology proposed in Fidan (2008) and the risk map structure employed in Eybpoosh (2010) were overviewed with the collaboration of the partner firm. It has been understood that although the ontology and methodology are reliable and applicable in practice, some kind of assistance is necessary for the decision-makers to assign risk and vulnerability ratings. Within this context, following topics are discussed through investigating the problem areas as well as recommending probable strategies, which constructs the major functions of the risk-mapping tool.

1) Decision-makers might be lack of knowledge about vulnerability sources for which they will assign ratings. Thus, they might rely on their own judgments about what does the related vulnerability source refer. It was argued that, indicators and attributes of each vulnerability source should be provided to decision makers. Hence, the incorporation of attributes is proposed to facilitate a rational and a systematic methodology for the assessment of vulnerability sources by providing a common language about vulnerability sources.

2) Similar to the some authors (i.e. Kıvrak et al. 2008; Yeo (1990); Tserng et al., 2009; Dikmen et al.; 2008), company experts also highlighted that current risk assessment methodologies highly rely on subjective judgments. They pointed out that, risk assessment should be carried out in a more objective and rational manner as well as facilitate an organizational knowledge in order to avoid relying on solely individual knowledge. It was discussed that, a lessons learned database is needed to capture previous project knowledge to reuse in forthcoming projects as well as to develop organizational risk memory. How the lessons learned database can be established, how gained knowledge can be stored in database, how the tool can help the decision makers by utilizing previous project knowledge, are the main issues discussed with the partner firm experts.

3) Although lessons learned database aids to collect, store and maintain risk event histories of previous projects, it was also argued that, organization members should also be able to transfer and document these risk events within the organization in order to enhance organizational learning. Thus, it was decided to incorporate an automatic report generation system from which the gained and stored knowledge as well as risk assessment results can be shared and transferred among organization members.

4) Generally, construction practitioners are not familiar with the risk management methodologies. Even if, they have been conducted any of the risk management steps, within this process they mostly utilize traditional methodologies, which generally rely on paperwork rather than computerized tools. Thus, an introductory knowledge about the risk-mapping tool and the risk assessment methodology employed in the tool should be given to the decision makers in order to enhance the reliability and the effectiveness of the tool. It was concluded to incorporate a help menu in which a brief description of the functions of the tool as well as underlying methodology of the risk assessment process, are introduced.

Based on the review on the available literature and the discussions held with the company experts, this study is an encouraging effort to fulfill the gap of the lack of an applicable risk assessment methodology for the international construction projects. The main objectives of this study can be summarized as follows;

- To recommend a risk assessment methodology for international construction projects which considers causalities among risk-related concepts as well as represents an overall risk map structure in which interrelated risk path chains are given.

- To develop a knowledge-based risk mapping tool that will be used to predict probable risk path scenarios on project cost overrun as well as to quantify severities of the risk-related concepts relating on cost performance of international construction projects.

- To determine vulnerability source attributes that will be used to identify triggering factors for the occurrence of these sources. The vulnerability source- attribute framework will further be incorporated within the risk-mapping tool.

- To develop a "lessons learned database" in which risk event histories of previous experiences of construction experts about cause-effect relations among risk-related concepts are stored. The database will further be used to strength organizational memory and facilitate organizational learning.

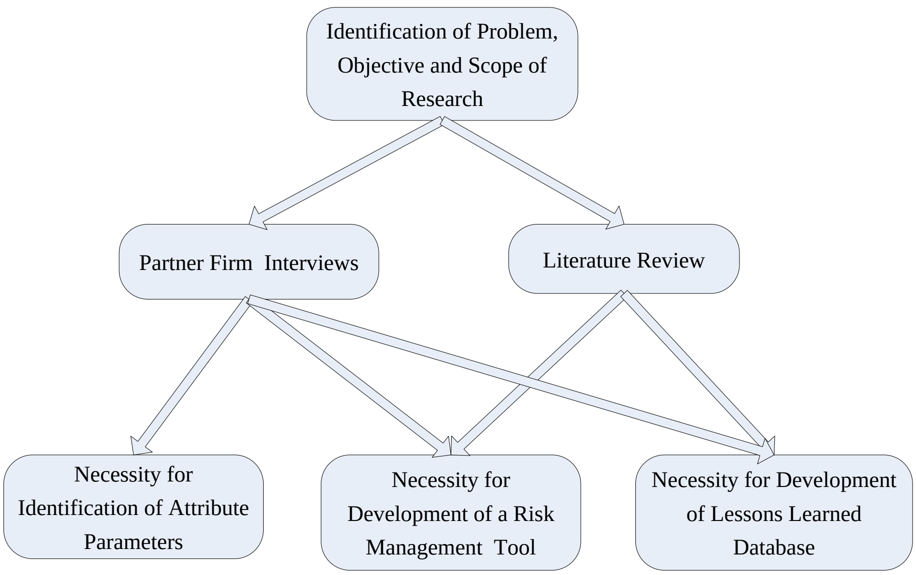

Figure 2.1: Schema of scope definition

2.7. Structure of the Risk Mapping Process

The risk-vulnerability ontology developed in the study of Fidan (2008) is the initial stage of the three subsequent studies on development of a knowledge-based risk-mapping tool. As a further attempt, Eybpoosh (2010) developed a risk map structure and proposed a risk assessment methodology based on the study of Fidan (2008). As a final stage of these two interrelated studies, in this thesis, based on the risk-vulnerability ontology and the risk map structure, a knowledge-based risk mapping tool is developed. In this section, the generic risk-vulnerability path structure is described and risk-related concepts used in this structure are overviewed. Then, the risk-vulnerability ontology, the risk-path structure and the risk map is demonstrated. Finally, underlying theory of the risk assessment methodology of the tool, Structural Equation Modeling (SEM) facilitated by Eybpoosh (2010), is briefly described as well as the reliability and the validity of the technique is given.

2.7.1. Definition of Risk- Related Concepts

Prior to the introduction of the risk-vulnerability ontology and the risk path structure, firstly the risk-related concepts that constitute the basic knowledge of the previous studies should be given.

2.7.1.1. Vulnerability

Vulnerability can be confused with risk (Ezell, 2007). A system's vulnerability represents the extent or the capacity of this system to respond to or cope with a hazard or a risk event (Zhang, 2007). "A system's vulnerability can be described from multiple aspects, such as its exposure to a hazard, its capacity to resist hazard impacts, and the possibility of slow recovery from hazard impacts" (Watts and Bohle, 1993). Zhang (2007) and Sarewitz et al. (2003) defined vulnerability as "systems innate characteristics and capacities the existence of which creates possibilities for future harms and their subsequent consequences". In their study, Fidan et al. (2011) claimed that risk assessment should incorporate "vulnerability" to represent actual consequences of risk events and changes in project conditions considering the project's vulnerability to risks as well as organizations' competency to manage risks. In other words, company factors and the project characteristics represent in what extent the project is vulnerable to risk events and its outcomes. Within the context of previous studies, it is accepted as vulnerabilities initiate various risk paths and first level of the risk paths (risk sources) and their magnitudes are affected by the magnitudes of the associated vulnerability factors.

2.7.1.2. Risk Source

Risk source is defined as any factor that has a potential to cause harm to a project (Standards Australia, 2004). In accord with their origin, Fidan et al. (2011) classified risk sources within two groups, adverse changes from initial project conditions or unexpected events. Eybpoosh et al. (2011) defined unexpected events as unforeseen events that “will either occur or not” and due to their unpredictable nature, their possibility of occurrence does not depend on the occurrence of any vulnerability factor or risk source. In other words, the risk path covering unexpected events initiates individually and directly results in cost overrun. In addition, adverse changes imply undesirable variations from the initial project conditions. In contrast to the unexpected events, adverse changes lead to cost overrun through initiating from some vulnerability factors and through the occurrence of some related risk path scenarios. In this research, eight risk sources implying adverse changes and one risk source designating unexpected events are studied.

2.7.1.3. Risk Event

A risk event is the occurrence of a negative happening (Standards Australia, 2004). Risk events can be described as variations (increases or decreases) in project goals (i.e. cost, time, quality, performance) due to occurrence of some related risk sources (Al-Bahar and Crandall, 1990). The underlying theory of the risk path structure of this research is that, risk sources lead to risk consequences through the occurrence of risk events. In other words, risk events are the intermediary factors among risk sources and risk consequence. In this study, risk events are mainly about variations in quality of work, amount of work, unit cost of work, productivity, as well as lags in cash flow, delays, and interruptions.

2.7.1.4. Risk Consequence

“Risk consequence describes the outcome of a risk event that causes deviation in project objectives” (Fidan et al. 2011). Al-Bahar and Crandall (1990) defined risk consequence as the outcome of risk event occurrence. In literature, risk consequence is accepted as the undesired variations in project objectives such as cost, time, quality, and safety (Al-Bahar and Crandall, 1990; Zhang 2007; Carr and Tah 2001). Within the context of the risk-path structure, risk consequence is characterized by the percentage of cost overrun in international construction projects. The occurrence scenarios of various risk paths are all finalize with the effect on cost performance of international projects and impact on other project objectives such as quality, duration, and safety are ignored.

2.8 Framework of Risk-Vulnerability Ontology

The major aim of the study of Fidan (2008) was developing a risk-vulnerability ontology "that can be used as the basis of a risk event history database that entails risk paths rather than individual risk sources and vulnerability factors that affect the impact of risks on a project". Within this context, Fidan (2008) identified potential risk-related factors leading cost overrun in international construction projects using the data of Turkish contractors doing business abroad. Author classified risk-related concepts as vulnerability, risk source, risk event and risk consequence in accord with their hierarchical order (inherited from their logic) within the risk paths in order to develop risk-vulnerability conceptual framework. Vulnerability sources were further identified and categorized based on their occurrence scenario on risk paths as; robustness source, resilience source and sensitivity source. Finally, authors constructed an ontology that relates risk and vulnerability factors to cost overrun based on the data collected through questionnaire. Figure 2.2 illustrates the generic risk-vulnerability path structure that constitutes the underlying theory of risk-vulnerability ontology reported in Fidan (2008). The path structure presents the causalities among the risk-related concepts. That is; vulnerabilities initiate first level of the risk paths (risk sources) and risk sources lead to risk consequences through the occurrence of risk events.

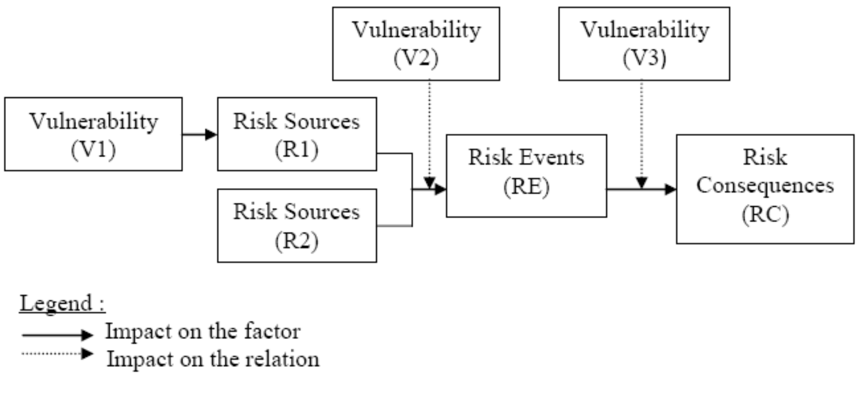

Figure 2.2: Generic Risk-Vulnerability Path Structure given in Fidan (2008)

In this study, risk-related variables as well as their occurrence scenario are accepted as in accord with the findings of Fidan (2008). Within this context, the risk map is comprised of 49 vulnerability sources associated with 12 vulnerabilities as well as 21 variables related with the 8 risk sources, 6 risk events and 1 risk consequence. To be noted that, in the study of Fidan (2008), the latent factor "Design Problems" is defined as vulnerability. However, in this study, it is accepted as a risk source, since it does not initiate any risk path. Table 2.1 presents the list of risk-related variables along with their types as were structured on the risk map.

Table 2.1: Risk-related variables

Type	No	Vulnerability	No	Vulnerability Source
Vulnerability (1)	**V1**	Adverse Country Related Conditions	**VS1**	Instability of Economic Condition
			VS2	Instability of Government
			VS3	Instability of International Relations
			VS4	Social Unrest
			VS5	High Level of Bureaucracy
			VS6	Immaturity of Legal System
			VS7	Restrictions for Foreign Companies
			VS8	Unavailability of Local Material
			VS9	Unavailability of Equipment
			VS10	Unavailability of Local Labor
			VS11	Unavailability of Local Subcontractor
			VS12	Unavailability of Infrastructure
	F2	Design Problems	**VS13**	Poor/Incomplete Design
			VS14	Design Errors
	V3	Project Complexity	**VS15**	Complexity of Design
			VS16	Low Constructability
			VS17	Complexity of Construction Method
	V4	Uncertainty of Geological Problems	**VS18**	Uncertainty of Geotechnical Investigation
	V5	Strict Requirements	**VS19**	Strict Quality Requirements
			VS20	Strict Environmental Requirements
			VS21	Strict Health & Safety Requirements
			VS22	Strict Project Management Requirements
	V6	Contract Specific Problems	**VS23**	Vagueness of Contract Clauses
			VS24	Contract Errors
	V7	Engineer's	**VS25**	Technical Incompetency of Engineer

Table 2.1.(Cont'd)

		Incompetency	**VS26**	Managerial Incompetency of Engineer
			VS27	Engineer's Lack of Financial Resources
	V8	Client's Incompetency	**VS28**	Client's Unclarity of Objectives
			VS29	Client's High Level of Bureaucracy
			VS30	Client's Negative Attitude
			VS31	Client's Poor Staff Profile
			VS32	Client's Lack of Financial Resources
			VS33	Client's Technical Incompetency
			VS34	Client's Poor Managerial/ Organizational Abilities
	V9	Adverse Site Conditions	**VS35**	Poor Site Supervision
			VS36	Lack of Site Facilities
Vulnerability (2)	**V10**	Contractor's Lack of Experience	**VS37**	Contractor's Lack of Experience in Similar Projects
			VS38	Contractor's Lack of Experience in Country
			VS39	Contractor's Lack of Experience in Project delivery System
			VS40	Contractor's Lack of Experience with Client
	V11	Contractor's Lack of Resources	**VS41**	Contractor's Lack of Financial Resources
			VS42	Contractor's Lack of Technical Resources
			VS43	Contractor's Lack of Staff
	V12	Contractor's Lack of Managerial Skills	**VS44**	Poor Project Scope Management
			VS45	Poor Project Time Management
			VS46	Poor Project Cost Management
			VS47	Poor Project Quality Management
			VS48	Poor Human Resource Management
			VS49	Poor Communication Management
			VS50	Poor Risk Management
			VS51	Poor Procurement Management
Risk Source (1)	**F13**	A.C. in Country Economic Conditions	**VS52**	Changes in Currency Rate
			VS53	Changes in Economic Indicators
	F14	A.C. in Laws& Regulations	**VS54**	Change in Taxation Policies
			VS55	Change in Laws & Regulations
	F15	Conflicts with Project Stakeholders	**VS56**	Conflict with Government
			VS57	Conflict with Engineer
			VS58	Conflict with Client
			VS59	Poor Public Relations

Table 2.1.(Cont'd)

	F16	A.C. in Performance of Client	**VS60**	Change in Performance of Client Representative
			VS61	Changes in Client's Staff/ Organization
			VS62	Change in Financial Situation of Client
	F17	Changes in Project Specifications	**VS63**	Scope Changes
			VS64	Design Changes
	F18	A.C. in Performance of Contractor	**VS65**	Change in Site/Project Organization
			VS66	Change in Functional Performance of Contractor
	F19	A.C. in Availability of Local Resources	**VS67**	Change in Availability of Labor
			VS68	Change in Availability of Material
			VS69	Change in Availability of Equipment
			VS70	Change in Availability of Subcontractor
	F20	A.C. in Site Conditions	**VS71**	Change in Geological Conditions
			VS72	Change in Site Condition
R S (2)	**V21**	Unexpected Events	**VS73**	War/ Hostilities
			VS74	Rebellion/ Terrorism
			VS75	Natural Catastrophes
Risk Event	**F22**	Delays/ Interruptions	**VS76**	Delays/ Interruptions
	F23	Decrease in Productivity	**VS77**	Decrease in Productivity
	F24	Increase in Amount of Work	**VS78**	Increase in Amount of Work
	F25	Decrease in Quality of Work	**VS79**	Decrease in Quality of Work
	F26	Increase in Unit Cost of Work	**VS80**	Increase in Unit Cost of Work
	F27	Lags in Cash Flow	**VS81**	Lags in Cash Flow
RC	**F28**	Cost Overrun	**VS82**	Cost Overrun

2.9 Framework of Risk Path and Risk Map

Based on the conducted risk-vulnerability ontology, Eybpoosh (2010) developed a risk map structure relating risk-related variables to cost overrun as well as constructed risk path models that emerged from occurrence scenario of these variables. Eybpoosh (2010) argued, "assessment of magnitude of individual risk factors regardless of probability of occurrence of a chain of risk events and probability of co-occurrence of several risk factors that emerge from the same source may result in underestimation of overall risk level of the project". Author suggested that rather than representing risk variables individually, they should be patterned on risk paths with considering causalities among them in order to achieve better visualization of project conditions. Within this aim, author identified 36 interrelated risk paths using the data of 166 projects carried out by Turkish contractors in international markets. Based on her findings, author constructed a risk map structure to represent cause-effect relations among risk-related variables and interrelations of risk paths. Interdependency coefficients of risk-related variables on the related risk paths and total impacts of each risk path on project cost performance were found by using Structural Equation Modeling (SEM). Figure 2.3 demonstrates the risk map structure identified in the study of Eybpoosh (2010) along with the interdependency coefficients of the risk-related parameters. Noticeably, the risk map is composed of 36 interrelated risk paths that were generated from 28 risk-related variables.

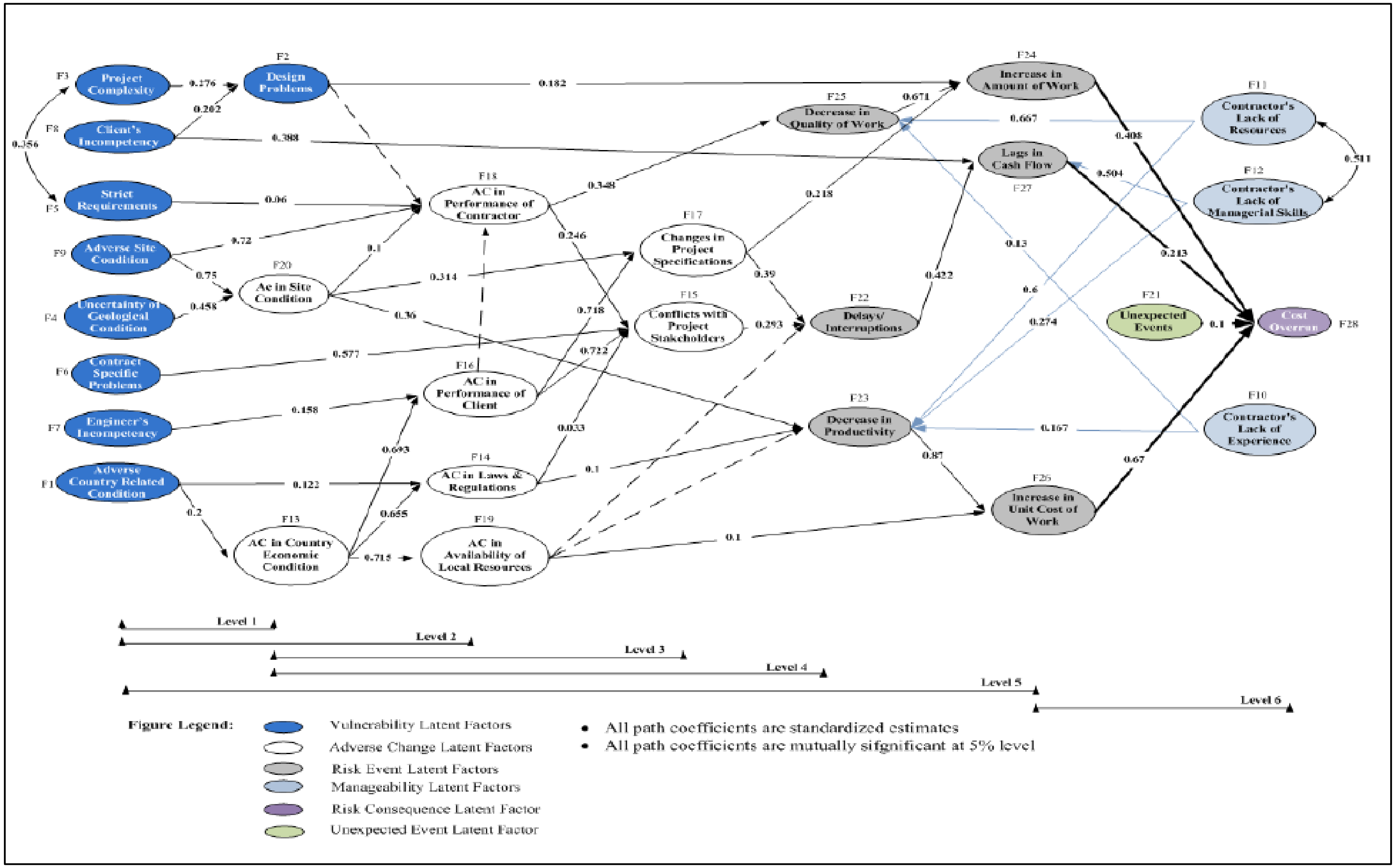

Figure 2.3: Risk map structure developed in the study of Eybpoosh (2011)

2.10 Overview of Structural Equation Modeling

Bentler (2006) described SEM as a collection of statistical techniques (i.e. Confirmatory Factor Analysis, Path Analysis, and Multiple Regression Analysis) that allows the representation and the measurement of possible direct and indirect interrelationships among variables at the same time. In recent studies in the field of construction engineering and management, SEM has been widely facilitated (Sarker et al., 1998; Wong et al. 2009) which allows the representation, estimation, and validation of "a hypothesized network of linear relations among the observable and latent variables" (Jöreskog and Sörbom, 1996). Within literature, SEM has been employed for the prediction of impacts of several variables on a single objective (i.e. project performance). Isik et al. (2010) utilized SEM to assess the impact of 'resource and capabilities', 'strategic decisions', 'project management competencies' and 'strength of relationships with other parties' on construction company performance. Ozorhon et al. (2007) investigated the impact of host country conditions and project related factors on international construction joint ventures performance (performance of project, partner, and IJV management) with using SEM. Kim et al. (2009) quantified 64 'performance influencing variables' (observed variables), 14 'major variables directly affecting project performance without hierarchical structure' (latent variables) on project performance. Wong et al. (2009) analyzed the relative importance of the relations among organizational learning styles and project performance through SEM. In her study, Eybpoosh (2010) argued that SEM is the most appropriate technique fitting to her research and facilitated SEM to quantify interdependency coefficients among risk-related variables as well as risk path chains.

2.11 Reliability and Validity of SEM

The hypothesized conceptual model of SEM is composed of a measurement model and a construct model. In the study of Eybpoosh (2010), the 28 measurement variables (i.e. vulnerability, risk source, risk event variables) constitute latent factors of the model and all were measured by 82 observed variables. The measurement models were analyzed through confirmatory factor analysis (CFA). In order to examine the reliability and the validity of the measurement models, "internal consistency of constructs", "convergent validity", "discriminant validity" test were utilized. "Internal consistency of constructs" measures reliability of models and covers tests of "unidimensionality" and "individual item reliability". Factor loadings measured in the study of Eybpoosh (2010) satisfy the condition of unidimensionality with values greater than 0.5, which was recommended in Hair et al.

(2006). All observed variables possess a sufficient degree of individual reliability by having "Cronbach's Alpha" coefficients greater than the threshold value of 0,7 which was recommended in Nunally (1978) and Hair et al. (2006). "Average variance extracted" is a metric used to measure convergent validity. All measurement models have a sufficient degree of convergent validity with having "average variance extracted" higher than 50 percent. The model satisfies the discriminant validity by having shared variance among distinct constructs less than the average variance shared among a construct and its indicators.

As a further approach, in order to evaluate whether the Risk-Path Construct Model can be statistically identified, Eybpoosh (2010) facilitated Bentler and Weeks method (Bentler and Weeks, 1980) in which all variables are considered either Independent (IV) or Dependent (DV). Bentler (2006) proposed that, in order to develop an identified model, degrees of freedom of the variables should have a positive value that is known data points should be larger than the unknown parameters. The risk-path construct model developed by Eybpoosh (2010) was over-identified, with 244 "number of unknown parameters", 3403 "data point", and 3159 "degrees of freedom". With satisfying univariate and multivariate normality, the data collected for 82 risk-related variables was considered as normally distributed and Maximum Likelihood (ML) was facilitated for the analysis purposes. In order to measure the properness of the Risk-Path Construct Model and to evaluate the fit and suitability of the assumed causal relationships to the actual data, Eybpoosh (2010) facilitated 4 distinct indices; "Comparative Fit Index" (CFI), "Non-Normed Fit Index" (NNFI), "Room Mean Square Error of Approximation" (RMSEA) and the ratio of "Chi-Square" to the "Degree of Freedom" (x2/DF). The test results confirmed that the construct model and the hypothesized causal relations could adequately represent the sample data.

2.12 Overview of Risk Assessment Methodology

The major aim of the risk mapping tool is to computerize the risk assessment methodology developed in the study of Eybpoosh (2010) that predicts severities of the risk-related variables as well as quantifies impacts of the risk path chains on the cost performance of international projects with the known vulnerability magnitudes. The prediction process initials with the assigning magnitudes for the vulnerability sources of the given vulnerabilities by decision-makers. Magnitudes of the vulnerability source ratings can be defined with the assistance of the lessons learned database and/or vulnerability source attributes. Methodologies for the development of lessons learned database and identification of vulnerability source attributes as well as their findings would be introduced in the further sections of this study. With the known vulnerability source magnitudes, the tool automatically quantify the severities of vulnerabilities, risk sources, risk events and risk consequence as well as total impacts of each risk path on risk consequence through the coefficients that were found by SEM. To be noted that, the detailed description of the risk assessment methodology employed in the risk mapping tool will be given in the fifth chapter of this study. However, introductory information is given here in order to announce ‘lessons learned database’ and ‘vulnerability source attributes’ concept incorporated in the risk mapping tool.

CHAPTER 3

METHODOLOGY FOR THE IDENTIFICATION OF VULNERABILITY SOURCE ATTRIBUTES

This chapter presents the research methodology employed for the development of the vulnerability source-attribute framework. Through section one to three, firstly, the definition of attributes, the importance of attribute identification and the objective of attribute identification in this study, is briefly introduced. In the fourth section, the reviews on the available literature associated with the identification of attributes, are given. In the fifth section, firstly the research methodology for the identification of vulnerability source attributes are introduced, the grouping of vulnerability sources, references selected for the identification test and illustrative examples of attribute extractions from literature review are explained. In the sixth section, the identified attribute parameters from the identification test along with their references are given. Finally, in the seventh section, the applicability of the identified attributes is demonstrated along with the one of the illustrative example of case studies.

3.1. Definition of Attributes

In available literature, different terms have been used to describe the indicators or triggering factors of occurrence of risk factors in construction projects. In this study, the term "attribute" has been selected to denote probable variables that may trigger the occurrence of vulnerability sources. A number of definitions of attribute from a variety of different references are given in Table 3.1. In this study, attributes are defined as events that trigger the occurrence of the related vulnerability sources and they denote the existence of the associated sources. Attributes can also be in the form of conditions or circumstances representing the inner characteristics of the related vulnerability sources.

Table 3.1: Definitions of attributes in literature

Definition	Author(s)
"Attributes are object–object part-of relationships and object–data–value properties which can help to semantically define and describe an ontological concept."	Sanchez (2010)
"Attribute is defined as high-level descriptions of the different poses, such as color, texture, shape, and so on." "The attributes is the representation of the basic characteristics of the object and considered as the object shape, texture, parts."	Brachman and Levesque (1985)
"Risk attributes refers to the events representing project development practices from planning, design, commissioning, operation to political, contractual and financial dimensions in the PPP procurement route."	Doloi (2012)
"Client attributes refer to clients' qualities displayed during the briefing process."	Ahmad et al. (2011)
Buildability attributes are "characteristics which directly or indirectly optimize integration of construction knowledge in the building process and balancing the various project and environment constraints to maximize project goals and building performance"	Mydin et al. (2011)

3.2. Importance of Attribute Identification

According to Fidan et al. (2011), attributes are one of the crucial components of the ontology since they represent the characteristics of elements and enable additional information about items involved in ontology. According to Elhag and Boussabaine (1999), the consideration of impacts of cost and duration attributes on project goals is a key success factor for utilizing reliable cost forecasting models and operating successful construction projects. In addition, the study of Almuhareb and Poesio (2004) revealed, "identifying a concept by its attributes leads to a better lexical description". Even though the identification of risk attributes is a significant attempt for the completeness and reliability of the process of risk identification, relatively less attention has been given in the examination of them.

3.3. Objective of Attribute Identification

As was introduced in the previous chapter, the initial step of the risk assessment methodology employed in the study, is assigning magnitudes to a list of vulnerability sources by decision makers. However, as was discussed with the partner firm experts, some vulnerability sources especially that are related with the political, economic, legal, or social conditions of a host country might not be understood by decision-makers since they are out of the construction engineering and management course and require special emphasis to gain knowledge about them. For instance, “Instability of Economic Growth” is one of the vulnerability sources, which should be evaluated and quantified by decision-makers. In order to assign a reliable rating, decision-makers should possess sufficient knowledge about the concept of the economic growth, factors that indicate a country’s economic growth or causative factors of its instability. However, decision makers might be lack of the listed knowledge especially in the case of they are inexperienced junior engineers. In addition, lack of sufficient time to investigate the given vulnerability source or excessive effort involved in investigation process, are some factors that limit to possess deep understanding of vulnerability sources. In these cases, decision makers might rely on individual judgments or experiences, which bring subjectivity in some extent when quantifying of vulnerability sources as well as limits the reliability of the risk assessment outcomes. In this study, it is argued that vulnerability source attributes representing the events that affect the occurrence of given vulnerability sources are essential for providing better understanding of the given sources as well as for guiding decision makers in assigning magnitude ratings for these sources. Moreover, it is discussed that brief descriptions of each attribute should also be given to provide introductory information about what the given attribute refers as well as how the given attribute affect the probability of the occurrence of the related vulnerability source. For instance, although attributes of “Instability of Economic Growth” are provided (i.e. Instability of Foreign Exchange Rate), it may still hard to understand what the instability of foreign exchange rate refer or how it affects the occurrence of “Instability of Economic Growth”.

3.4. Literature Review on Previous Attribute Identification Approaches

Within available literature, several authors have been attempted to carry out “attribute identification” to represent the inner characteristics, elements, indicators of the related research disciplines. The reviewed disciplines cover, construction engineering, and management, construction safety management, sustainability, data and knowledge engineering, collaborative working and so on.

Gunderson and Cherf (2012) conducted a qualitative research to investigate general contractors’ perceptions on competencies and attributes of subcontractors. From the general contractors’ point of view, authors explored six major attributes that subcontractors should possess as well as identified four other attributes indicating incompetency of subcontractors. Through literature survey and a personal interview, Jha and Iyer (2007) identified 24 major attributes associated with the project coordinators. By carrying out a factor analysis, authors classified these attributes into three group of skills; “team building skills”, “contract implementation skills” and “project organization skills” as well as analyzed the importance of these attributes on the success and failure of projects. Esmaeili and Hallowell (2012) developed an attribute based risk identification and assessment model that aid designers and planners to investigate interdependency among safety risks associated with the specific activities and building components. Through reviewing an extensive amount of injury reports and the available literature, authors collected 34 attributes and classified them into four folds: physical characteristics, jobsite location, and equipment, lifting and handling objects. The model is further be used to quantify the safety risk and hazardous attributes that result in stuck-by accidents. Bell and Stukhart (1986) identified and discussed the attributes of material management systems of construction projects. These attributes are; “planning and communication”, “material takeoff and engineering interface”, “vendor inquiry and evaluation”, “purchasing”, “expediting and shipping”, “warehousing, receiving and material distributions” and “material control”. Ahmad et al. (2011) investigated and analyzed client-related attributes that affect the level of success of construction projects. Of the identified 31 critical attributes, authors arranged them into three distinct subsets: “quality of client’s representatives”, “brief management efforts” and “commitment of client’s organization”. Alzahrani and Margaret (2012) carried out a review on literature to identify the impact of contractors’ attributes on success of construction projects from the perspective of post construction evaluation. As was given in Figure 3.1, authors investigated 35 critical success factors associated with the 10 success attributes. The identified success attributes are; financial attributes, management attributes, technical attributes, past experience attributes, past performance attributes, organization attributes, environmental attributes, health and safety attributes, quality attributes and resources attributes. Mydin et al. (2011) facilitated on extensive literature review to investigate previous researches studying buildability concepts, attributes, and principles in the design phase of construction projects. Through the examination of previous studies, authors identified 19 buildability attributes and analyzed the level of importance of design building attributes in Malaysian construction projects. In their study, Radujkovic and Car-Pusic (2004) identified 39 attributes associated with the 11 risk sources in construction projects and employed a breakdown approach to structure risk sources and their attributes. The breakdown of identified risk sources and their attributes in the study of Radujkovic and Car- Pusic (2004) are given in Figure 3.2. By reviewing the available literature and conducting interviews with project management personnel, Zavadskas et al. (2008) identified attributes and sub-attributes affecting the process of project manager selection in construction projects. Of the identified 21 attributes, authors measured the level of importance of attributes on selection process as well as analyzed the multi-attribute evaluation of a selected group of project managers. By setting the literature reviews, questionnaire surveys and interviews as the underlying methodology, Toor and Ogunlana (2009) explored 13 negative personal attributes and 12 organizational factors that make the project managers ineffective and incompetent in leadership ability. As a further attempt, authors discovered “environmental neutralizers” influencing the project managers’ leadership performance in large construction project operating in Thailand. Through the examination of available literature, Doloi (2012) explored 42 risk attributes that affect the cost, time, and operational performance of PPP projects. In his study, Doloi (2012) quantified the impact of these attributes on the related performance domains, investigated similarities, and differences among risk attributes, and developed predictive models on the performance of PPP projects. Chan et al. (2004) conducted a review on related literature to identify and classify factors influencing success of construction projects. Authors identified 44 attributes associated with the five success groups: project related factors, procurement related factors, project management factors, project participants factors and external factors. Figure 3.3 demonstrates the conceptual framework of success groups and their corresponding attributes employed by Chan et al. (2004). By reviewing the existing literature, Elhag and Boussabaine (1999) identified 67 attributes associated with the time and cost performance of construction projects and classified them into six subsets: client characteristics, consultant and design parameters, contractor attributes, and project characteristics, contract procedures and procurement methods, and external and market conditions. As a further approach, authors analyzed the importance of these subsets on project time and cost performance by using Kendall’s concordance test.

Number	Success attributes	Critical success factors (CSFs)
1	Financial attributes	Turn over history Credit history Bonding capacity Cash flow forecast
2	Management attributes	Staff qualification Management capability Site organisation Documentation
3	Technical attributes	Contractor's IT knowledge Knowledge of particular construction method Work programming Experience of technical personnel
4	Past experience attribute	Type of past project completed Size of past project completed Length of time in business Experience in the region
5	Past performance attributes	Failure to have completed a contract Contract time overruns Contract cost overruns Past record of conflict and disputes
6	Organization attributes	Size of the company Company image Age in business Litigation tendency
7	Environmental attributes	Waste disposal during construction Environmental plan during construction Materials and substances used in the project
8	Health and safety attributes	Health and safety records Occupational safety and health administration rate (OSHAIR) Experience modification rating (EMR)
9	Quality attributes	Quality control Quality policy Quality assurance
10	Resources attributes	Adequacy of labour resources Adequacy of plant resources

Figure 3.1: Success attributes and critical success factors (Alzahrani and Margaret, 2012)

EXTERNAL SOURCES –outside the project		INTERNAL SOURCES – inside the project	
LEGISLATIVE	1 - local regulations	CONTRACT	1 – unrealistic deadline
	2 – permits and agreements		2 - unrealistic price
	3 – law changes		3 – other contract provisions
	4 – standards	TECH. DOCUM.	1 – delay
POLITICAL	1 – policy changes		2 – incompleteness
	2 – elections		3 – imprecision
	3 – war		4 .- new solutions as a consequence of 2 and 3
	4 – existing agreements	ORGANIZATION	1 – bad management
ECONOMICAL	1 – economic regulations		2 – bad organization of works
	2 – price rises	TECHNOLOGY	1 – poorly chosen tech. solutions
	3 – exchange rates		2 – obsolete technology
	4 – financing conditions	RESOURCES	1 – shortage of workers
	5 – economic policy changes		2 – shortage of machinery
SOCIAL	1 – education, culture		3 – machinery breakdowns
	2 – seasonal work		4 – late delivery of materials
	3 – strike	HUMAN FACTOR	1 – productivity
	4 – human fluctuation		2 – sick leaves
NATURAL	1 – climate		3 – motivation
	2 – soil		4 - errors and omissions
	3 – subterranean waters		
	4 – natural disasters		

Figure 3.2: Breakdown structure of attributes (Radujkovic and Car-Pusic, 2004)

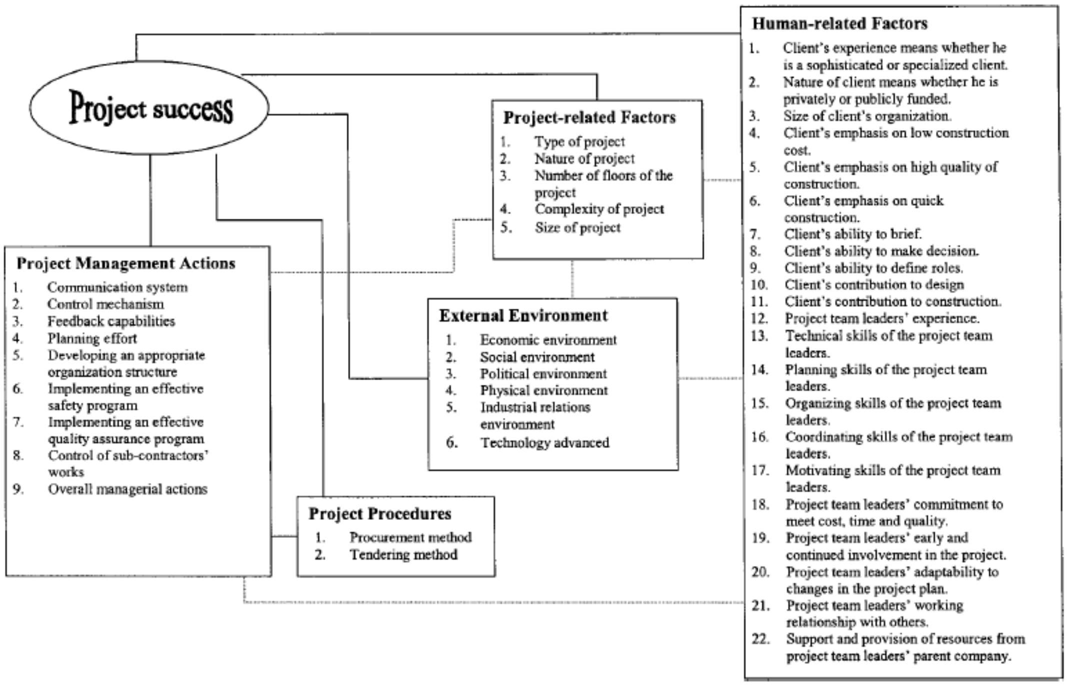

Figure 3.3: Attributes of project success groups (Chan et al.,2004)

3.5. Methodology for Attribute Identification

The identification of risk variables affecting project objectives of construction projects is one of the widely studied and published topics; however, there is no other or limited attempt focusing on attributes that indicate the triggering factors for the occurrence of these risk variables. Although, some other researchers have been endeavored to identify attributes associated with the several research domains in the field of construction engineering and management, these studies suffer from comprehending overall construction risk attributes indeed, they served limited amount and type of attributes. In addition, these studies are lack of giving detailed additional information about the variables and defining their characteristics. However, all of these researchers facilitated a common underlying methodology for the identification of attributes; that is conducting a review on literature. Independent from their research domains, all mentioned authors in the previous section, conducted detailed literature surveys to investigate probable attributes representing their research domains. In this study, utilizing a review on the available literature constitutes the underlying methodology for the exploration of a list of attributes associated with the vulnerability sources; however, a more systematic review approach was developed and applied in contrast to other authors. The approach undertaken for the development of attributes comprised two attempts; a literature review to identify attributes through

‘Identification Test’, and a review on case studies to investigate the applicability of the identified attributes.

Within this context, several books, journal papers and experts interviews are consulted in the attribute development process and a consensus framework was reported in Appendix-A. However, conducted steps to develop vulnerability source- attribute framework are discussed and illustrative examples are provided in this section. This approach consists of: (1) identification of attributes through Identification Test, (2) review on the identified attributes by partner firm experts, (3) validation of the applicability of the identified attributes.

3.5.1. Identification of Attributes by Identification Test

“Identification Test” refers to the investigation of key issues from the previous studies by extracting relevant key words from the related literature source. It is meaningful and useful to facilitate this method especially when the key issues are close with previous studies but limited researchers have been attempted to identify them (Wu et al., 2008). In available literature, “Identification Test” has been used in the studies of several researchers such as; Wu et al. (2008), Tyler and Matthews (1996) and Chan et al. (2003). For instance, Wu et al. (2008) employed the “Identification Test” to identify the attributes of collaborative working in construction industry. In their study, authors collected 26 papers and through the review of these papers, identified 20 attributes associated with the collaborative working. Within the context of the “Identification Test” employed in this study, a detailed literature review was conducted to explore attributes of vulnerability sources. However, prior to the review on available literature, firstly the vulnerability sources are grouped in accord with their relevant research domains.

3.5.1.1. Research Field Groups

The general vulnerability- vulnerability source framework developed by Eybpoosh (2010) is given in Table 2.1. Although vulnerability sources grouped in the study of Eybpoosh (2010), effectively represent characteristics of their relevant vulnerabilities, in this study it is needed to re-group them for the sake of simplicity when carrying out “Identification Test”. This is because; vulnerability sources representing vulnerability can vary in concepts and in relevant research domains. For instance, “Unavailability of Material” and “Instability of Economic Growth” were grouped under the vulnerability of “Adverse Country Related Conditions”;

however, studying characteristics of material-related conditions and economic variables of a country requires reviews on different types of literature sources. Thus, vulnerability sources are re-grouped based on their research fields and ten categories fit to the representation of all vulnerability sources. These groups are; General Characteristics of Country (G1), Construction Resources (G2), Geological Conditions (G3), Requirements (G4), Contract (G5), Project Participants (G6), Construction Site (G7), Project Management (G8), Financial Conditions (G9), Project Characteristics (G10). During the "Identification Test", probable sample studies are selected based on the fields of these vulnerability source groups. The groupings of research domains of "Identification Test" along with the classified vulnerability sources are given in Table 3.2. To be noted that, the categorization of vulnerability sources is further revised and attributes of vulnerability sources are synthesized considering their original framework developed in Eybpoosh (2010).

Table 3.2: Groupings of vulnerability sources

ID	Group Name	Relevant Vulnerability Sources
G1	**General Characteristics of Country**	Instability of Economic Condition (VS1), Instability of Government (VS2), Instability of International Relations (VS3), Social Unrest (VS4), High Level of Bureaucracy (VS5), Immaturity of Legal System (VS6), Restrictions for Foreign Companies (VS7), Contractor's Lack of Experience in Country (VS38)
G2	**Construction Resources**	Unavailability of Local Material (VS8), Unavailability of Equipment (VS9), Unavailability of Local Labor (VS10), Unavailability of Local Subcontractor (VS11), Unavailability of Infrastructure (VS12), Contractor's Lack of Technical Resources (VS42), Contractor's Lack of Staff (VS43)
G3	**Geological Conditions**	Uncertainty of Geotechnical Investigation (VS18)
G4	**Requirements**	Strict Quality Requirements (VS19), Strict Environmental Requirements (VS20), Strict Health & Safety Requirements (VS21)
G5	**Contract**	Vagueness of Contract Clauses (VS23), Contract Errors (VS24)
G6	**Project Participants**	Technical Incompetency of Engineer (VS25), Managerial Incompetency of Engineer (VS26), Client's Unclarity of Objectives (VS28), Client's High Level of Bureaucracy (VS29), Client's Negative Attitude (VS30), Client's Poor Staff Profile (VS31), Client's Technical Incompetency (VS33), Client's Poor Managerial/ Organizational Abilities (VS34), Contractor's Lack of Experience with Client (VS40)
G7	**Construction**	Poor Site Supervision (VS35), Lack of Site Facilities (VS36)

Table 3.2.: (Cont'd)

	Site	
G8	**Project Management**	Poor Project Scope Management (VS44), Poor Project Time Management (VS45), Poor Project Cost Management (VS46), Poor Project Quality Management (VS47), Poor Human Resource Management (VS48) Poor Communication Management (VS49), Poor Risk Management (VS50), Poor Procurement Management (VS51), Strict Project Management Requirements (VS22)
G9	**Financial Conditions**	Engineer's Lack of Financial Resources (VS27), Client's Lack of Financial Resources (VS32), Contractor's Lack of Financial Resources (VS41)
G10	**Project Characteristic**	Complexity of Design (VS15), Low Constructability (VS16), Complexity of Construction Method (VS17), Contractor's Lack of Experience in Project delivery System (VS39), Contractor's Lack of Experience in Similar Projects (VS37)

3.5.1.2. Sample Study Selection

Construction engineering and management journals constitute a thumping majority of the selected and reviewed journals within the context of the "Identification Test". These journals are; International Journal of Project Management, Journal of Construction Engineering and Management, Journal of Management in Engineering, and Construction Management and Economics. To be noted that, these journals have high quality scores and the papers from these journals are widely cited by other authors (Wu et al., 2008). Sample papers from relevant journals are selected by searching keywords, which are closely related with the field of vulnerability sources, from title or abstract. To be noted that, in this study the vulnerability sources are excessive in amount as well as cover a broad range of research topics. Thus, within the context of the "Identification Test", extreme amount of sample papers are collected to identify vulnerability source attributes. Extensive reviews and close examinations have been carried out on available references in order to explore attributes of given vulnerability sources. The journal papers and books studying specific topics and research fields (i.e. political, social, and economic conditions of a country, health and safety requirements) as well as previous studies investigating causes of project cost and time overrun are the root references of the test. The studies covering specific research areas are examined under the heading of above-mentioned categories, however the studies investigating causes of cost and time overruns could not be studied under any group of research areas. This is because; these studies cover high variety of variables associated with a wide gap of groups of research domains. The detailed descriptions of reviewed samples papers along with their relevant research group, are given in Table 3.3. Collected literature references are listed in alphabetical orders of surnames of initial authors.

Table 3.3: Sample papers

ID	Reference	Contents of studies	Group
1	Abd El-Razek et al. (2008)	Addressed causes of delay in construction projects when operating in Egypt. In total 32 delay factors were identified and a questionnaire survey was conducted to identify most important causes from point of view of project participants.	All
2	Aibinu and Odeyinka (2006)	Assessed relative importance of 44 time overrun factors associated with Nigerian construction projects.	All
3	Aisen and Veiga (2011)	Explored the impact of political instability on economic growth by utilizing system-GMM estimator that measures the data collected from 169 countries from 1960 to 2004.	G1
4	Akinci and Fischer (1998)	Used knowledge maps for demonstration of relationships among uncontrollable risk factors (i.e. economic factors, political risk factors, client related factors and subcontractor related factors) and cost overrun variables (i.e. unit cost, estimated quantity, and final unit cost).	G1, G6
5	Akintoye and MacLeod (1997)	Conducted a questionnaire survey and literature review to investigate risk perception of contractors, organizational risk management, risk premium and management in projects, and current risk analysis and management techniques.	G5, G8
6	Arditi et al. (2002)	Investigated constructability reviews of design firms as well as identified factors enhancing and constraining constructability.	G10
7	Arditi and Gunaydın (1997)	Investigated factors that affect quality, and elements of total quality management in construction process (i.e. training, management commitment and leadership, teamwork).	G4
8	Assaf and Al-Hejji (2006)	Identified 73 causes of delay factors associated with the construction projects in Saudi Arabia. As a further approach, assessed relative importance of these factors based on the perceptions of project participants.	All
9	Azhar et al. (2008)	Investigated major cost overrun factors in the construction industry of Pakistan and comprehended 42 factors through literature review and questionnaire survey.	All
10	Chan and Kumaraswamy (1996)	Evaluated relative importance of previously identified causes of time overruns in construction projects operated in Hong Kong. Authors analyzed 83 delay factors that were categorized into eight folds.	All
11	Chapman (2001)	Overviewed the steps of risk identification and assessment process of design projects and evaluated the impact of these	G1, G6, G10

Table 3.3.: (Cont'd)

		steps on the effectiveness of risk assessment.	
12	Chen et al. (2000)	Proposed a systematic approach to deal with environmental pollution and/or hazards caused by urban construction projects that were carried out in China.	G4
13	Choudhry et al. (2008)	Summarized construction safety elements (i.e. safety policy and standards, safety organization, safety training) as well as conducted an exploratory study to explain a successful safety management system with the collaboration of a leading construction company of Hong Kong.	G4
14	Chui and Bai (2010)	Classifed contract clauses into six subcategories and facilitated SPSS computer software to analyze differences among general conditions of construction contracts of United States and China	G5
15	Dione et al. (2005)	Identified probable environmental risks of construction projects and conducted a study to measure current environmental risk management practices employed by Canadian construction industry.	G4
16	Edum-Fotwe and McCaffer (2000)	Investigated attributes required for project management competency as well as identified how managers acquire knowledge and develop skills in todays' developing project management environment.	G8
17	Enhassi et al. (2009)	Identified 110 time overrun and cost overrun factors in construction projects while operating in Gaza Strip as well as grouped these factors into 12 categorizes (i.e. project-related, contractors' responsibility, contractual relationships).	all
18	Eriksson and Westerberg (2011)	Developed a testable holistic procurement framework to examine effects of procurement related factors and procedures on construction project performance.	G8
19	Foster (2008)	Analyzed and reported the key infrastructure elements (i.e. energy, transportation, water use) of Africa.	G1
20	Haberfeld and Cohen (2007)	Discussed labor market discrimination and earnings inequality of the Israeli labor market between 1975- 2001.	G1
21	Hartmann et al. (2009)	Determined four subcontractor selection criteria (price, technical know-how, quality and cooperation) of contractors as well as conducted a choice-based conjoint experiment to investigate relative importance of four criteria in the contractors' point of view.	G2
22	Huemann et al (2007)	Summarized previous studies on human resource management through a literature review as well as facilitated a model to identify critical human resource management elements of a project-oriented company.	G8
23	Isik et al. (2010)	Explored the impact of 'resource and capabilities', 'strategic decisions', 'project management competencies' and 'strength of relationships with other parties' on 'construction company	G8

Table 3.3.: (Cont'd)

		performance'.	
24	Jayadev and Reddy (2011)	Suggested a taxonomy relating different attributes of inequalities between groups as well as employed a software package to measure the degree of inequality among these groups.	G1
25	Jia et al. (2011)	Developed program management organization maturity integrated model for the mega projects operated in China. An organizational management sub model and a process management sub model were incorporated in the model.	G8
26	Kaming et al. (1997)	Explored the causative factors of time and cost overruns in high-rise construction projects operated in Indonesia.	All
27	Kleiner et al. (2008)	Developed a rapid universal safety and health system for construction projects. The system comprised of four parts; organizational and managerial structure, technical subsystem, personnel subsystem and internal environment.	G4
28	Kumar (2006)	Discussed how the availability of infrastructure can be measurement, defined infrastructure components, and assessed the role of infrastructure availability on foreign direct investment.	G2
29	Lam and Chow (1999)	Identified financial risk variables and investigated the importance of these variables when carrying out Build-Operate- Transfer (BOT) projects.	G1
30	Lee and Arditi (2006)	Developed a model to measure the total quality performance of design/build construction companies by facilitating quality function deployment.	G4
31	Ling and Hoang (2010)	Identified political, economic and legal risks faced by foreign companies while undertaking construction projects in Vietnam.	G1
32	Ling and Hoi (2006)	Identified risks that Singapore architecture, engineering and construction (AEC) companies can face while carrying out construction projects in India.	G1, G3, G4, G6
33	Ling and Lim (2007)	Identified financial and economic risks when foreign firms carrying out construction projects in China as well as suggested a risk management framework to manage them.	G1
34	Ling and Low (2007)	Summarized the legal risks that foreign architectural, engineering and construction companies faced while undertaking projects in China.	G1
35	Long et al. (2004)	Investigated major problems associated with the large construction projects in developing countries as well as grouped these problems under five folds (i.e. incompetent designers/contractors, social and technological issues).	G5, G6
36	Lum (2006)	Discussed the causes of social unrest in China, analyzed profiles of the protest groups, and explained the respond of government to protest activities, evaluated trends and	G1

Table 3.3.: (Cont'd)

		implications for government policies.	
37	Mahdi and Alreshaid (2005)	Facilitated AHP integrated with a multi-criterion decision-making methodology in order to enhance selection process of project delivery method.	G6
38	Marzouk et al. (2008)	Grouped engineer-related delays into three folds and utilized a knowledge-based expert system in order to model and assess claims associated with the engineer-related delays.	G6
39	Matthes (2010)	Defined attributes culture, globalization and international relations of a country as well as discussed interdependencies among them.	G1
40	Mawdesley et al. (2002)	Analyzed general site layout problem in construction projects with using genetic algorithms.	G7
41	Miljkovic and Rimal (2008)	Defined the term of political instability, investigated attributes of political instability and evaluated how socio-economic factors influence political instability by utilizing a cross-country analysis.	G1
42	Mulholland and Christian (1999)	Suggested a systematic risk assessment approach to define and quantify uncertainty involved in construction schedules by facilitating a decision analysis technique integrated with a mathematical model.	G8
43	Ozorhon et al. (2007)	Investigated the impact of host country conditions and project related factors on joint venture performance of international construction projects through SEM.	G1
44	Perry and Hayes (1985)	Identified 29 primary risk sources involved in construction projects and grouped them into 9 folds (i.e. physical, environmental, design, logistics, financial, legal).	G1, G8
45	Qureshi et al. (2010)	Constructed 7 political instability index variables (i.e. general strikes, demonstrations, riots, government longevity, and analyzed the interrelations among political instability and economic development of Pakistan.	G1
46	Sambasivan and Soon (2007)	Addressed 28 causes of delays and 6 main effects of them on project completion (i.e. time overrun, cost overrun, disputes) in Malaysian construction industry.	G6, G8
47	Serpell (1999)	Investigated benefits and limitations of integrating quality systems in construction projects by demonstrating a case study from Chile.	G4
48	Shane et al. (2009)	Identified 18 different cost escalation factors of construction projects, classified them as internal and external risks, and verified these factors by conducting interviews with 20 state highway agencies.	G6, G8
49	Shen et al. (2001)	Identified risks associated with sino-foreign construction joint ventures in China and facilitated a risk significance index to assess the relative importance among identified risks.	G1, G6

Table 3.3.: (Cont'd)

50	Singh and Tiong (2006)	Grouped contractor selection criteria into five folds (i.e. contracting company's attributes, past performance of the contractor, financial capability of the contractor, and measured the relative importance of these folds.	G1, G6
51	Sun and Meng (2009)	Developed two taxonomies for causes and effects of change clauses in order to use them in change management process.	G6
52	Sveshnikov et al. (2009)	Developed a model to analyze the tension of international relations among countries.	G1
53	Tabassi and Abu Bakar (2009)	Investigated human resource management practices of construction projects by conducting 120 sets of questionnaires to the leading companies in Iran.	G6, G8
54	Tam al. (2002)	Identified planning sequence of site layout facilities in construction projects by using nonstructural fuzzy decision support system.	G7
55	Thevendran and Mawdesley (2004)	Identified human risk factors of construction project, investigated perception of construction stakeholders and presented current mitigation practices about human risk factors.	G6, G8
56	Wang et al. (1999)	Identified political risks involved in BOT projects operating in China as well as evaluated contract clauses about political and force majeure risks by conducting an international survey.	G1
57	Zhi (1995)	Identified risks involved in international construction projects as well as suggested a risk assessment technique that integrates risk probability analysis with risk impact assessment.	G5
58	Zou et al. (2007)	Identified critical risk factors emerged in development phase of the construction projects and analyzed them from project stakeholder (i.e. risks related to clients, designers, contractors) and project lifecycle (i.e. feasibility, design) perspectives.	G1, G4, G6, G8

In addition to the journal papers, some sample books are selected and used when identifying attribtes. These books are as follows; Craig (2004), Harris and McCaffer (2001), Hoffman, Mondy et al. (1980), Jackson and Sorensen (2007), Meredith and Mantel (2011), PMBoK (2008), Smith (1999) and Yates (2007). These books are labeled as (59), (60), (61), (62), (63), (64), (65), (66), and (67), respectively.

3.5.1.3. Review on Sample Studies

Selected sample journal papers and books are reviewed and analyzed in order to explore vulnerability sources attributes. In most of the studies given in Table 3.3, so-called attributes are referred as variables, sources, causative factors, effects, or indicators of the related research fields. In this study, attributes are chosen in accord with the attribute selection criteria that are recommended and utilized in the study of Wu et al. (2008). Firstly, selected attributes are considered by the authors as critical events in the representation of the relevant topic. In addition, they can represent the characteristics of the related vulnerability source as well as reflect the definition and the description of the associated vulnerability sources. Finally, they share common understanding in literature as well as among the practitioners of the construction industry.

To figure out an example for how the attributes of a given vulnerability source are identified, a part of the verbal statements of the refereed papers are presented below. The example demonstrates extraction of attributes that are related with the vulnerability source of 'Instability of Government' from the studies of Ling and Hoang (2010), Qureshi et al. (2010), and Miljkovic and Rimal (2008). The statements directly taken from the papers are represented in quotation mark. The key words selected from the statements of authors are underlined and their reviews are given in Table 3.4, Table 3.5, Table 3.6. To be noted that, all vulnerability source attributes are identified with the same methodology along with the verbal analysis of the literature review.

3.5.1.3.1. Identification of Attributes of 'Instability of Government'

Sample paper 31: Statement from the study

"Examples of macro political risks include revolutions, civil wars, nationwide strikes, protests, riots, and mass expropriation."

Table 3.4: Extracted attributes from the study of Ling and Hoang (2010)

High level of revolutions in the history of the country
Occurrence of civil wars
High level of nationwide strikes
High level of riots

Sample paper 41: Statement from the study

"...revolutions are a sign of political instability and they can be caused by discontent and dissatisfied individual."

"Political instability represented by irregular or regular government changes always indicated certain level of dissatisfaction among people in a country with their economic or social status, current policies or future prospects. If socio- economic conditions in a country are perceived by the (majority of) population as good, changes are not likely to take place."

Table 3.5: Extracted attributes from the study of Miljkovic and Rimal (2008)

Poor support for government
Lack of government continuity
High level of revolutions in the history of the country
Dissatisfactions from the economic indicators

Sample paper 45: Statement from the study

"The total number of general strikes, demonstrations, riots, government longevity, change of government including coups, war and regime type have all been used as indicators of political instability and thus are used to construct a composite index of political instability."

Table 3.6: Extracted attributes from the study of Qureshi et al. (2010)

Lack of government continuity
Occurrence of civil wars
High level of nationwide strikes
High level of riots

After the analysis of sample studies, the identified attributes are listed along with reference studies from which attributes are extracted. Table 3.7 gives the list of attributes of vulnerability source 'Instability of Government'. As a further approach, the listed attributes are synthesized as well as relevant reference studies are captured with their reference ID's that have been previously labeled in Table 3.3. Final attribute list of 'Instability of Economic Growth' is given Table 3.8.

Table 3.7: List of identified attributes

Extracted attributes	Reference
- High level of revolutions in the history of the country - Occurrence of civil wars - High level of nationwide strikes - High level of riots	Ling and Hoang (2010)
- Lack of government continuity - Occurrence of civil wars - High level of nationwide strikes - High level of riots	Qureshi et al. (2010)
- Poor support for government - Lack of government continuity - High level of revolutions in the history of the country - Dissatisfactions from the economic indicators	Miljkovic and Rimal, (2008)

Table 3.8: Final attribute list

Attribute Name	Refereed Paper ID
Poor support for government	(41)
Lack of government continuity	(41), (45)
High level of revolutions in the history of the country	(31), (41)
Occurrence of civil wars	(31), (45)
High level of nationwide strikes	31), (45)
High level of riots	31), (45)
Dissatisfaction from the economic indicators	(41)

3.5.2. Review on the Identified Attributes by Partner Firm Experts

In order to justify the relevancy of vulnerability source attributes, the attributes identified through the "Identification Test" is further reviewed by the partner firm experts. Firstly, experts requested to explore the relevancy of attribute descriptions with the given attribute names and then discuss in what extent the identified attributes could represent the events and conditions that trigger the occurrence of the corresponding vulnerability sources. Although experts justified that given descriptions can briefly explains and exemplifies what the identified attributes refer, they claimed that there are some missing attributes that represents the characteristics of the given vulnerability sources. For example, experts argued that additional attributes should be defined for the vulnerability source of 'Client Negative Attitude' and 'Contractor's Lack of Experience in Similar Projects'. Thus, 'bad reputation of client', 'difficulties to arrange meetings' and 'negative attitude towards project parties' are added as attributes of 'Client Negative Attitude'. In addition, 'lack of experience in similar type of projects', 'lack of experience in projects having similar size', 'lack of experience in projects having similar location', 'lack of experience in projects having similar construction technology/method' are defined as attributes that represent vulnerability source of 'Contractor's Lack of Experience in Similar Projects'.

3.6. Attribute Parameters

Through the close examinations of the 58 sample papers and 9 sample books as well as the reviews conducted by partner firm experts, a list of attributes are identified and the consensus vulnerability source- attribute framework is given in Table 3.9. To be noted that, attributes identified through the Identified Test is given with their reference ID and those identified by the partner firm experts are labeled as '(PFE)'.

Table 3.9: Vulnerability source attributes

ID	Attributes	Reference ID
VS1- Instability of Economic Conditions		
1	Low level of Gross Domestic Product	(3)
2	Instability of foreign exchange rates	(29), (31), (33), (43)
3	Instability of interest rate	(29), (31), (33)
4	High level of Inflation	(29), (31), (33), (43)
5	Unsatisfactory level of international trade and foreign investments	(3)
6	Instability of political conditions	(3), (45)
VS2- Instability of government		
7	Poor support for government	(41)
8	Lack of government continuity	(3), (41), (45)
9	High level of revolutions in the history of the country	(31), (41)
10	Occurrence of civil wars	(4), (31), (45)
11	High level of nationwide strikes	(4), (31), (45)
12	High level of riots	(31), (45)
13	Dissatisfaction from the economic indicators	(41)
VS3- Instability of international relations		
14	Lack of alliances	(39), (52)
15	Poor role of country for the globalization	(39)
16	Poor trade relations with other countries	(52)
17	Negative declarations of media	(52)
18	Level of threats for national security	(63)

Table 3.9.: (Cont'd)

19	Poor economic relations	(63)
20	Undesirable history of country	(31)
VS4- Social Unrest		
21	High level of wage inequality	(36)
22	High level of nationwide strikes	(4), (31), (45)
23	Occurrence of civil wars	(4), (31), (45)
24	High level of protests and demonstrations	(36) (45)
25	High level of income inequality	(20), (24), (36)
26	High level of education and health inequality	(20), (36)
27	Lack of institutions that protect human rights	(36)
28	High level of labor market discrimination	(20)
29	High level of gender inequality	(24)
30	High level of racial inequality	(24)
VS5- Level of bureaucracy		
31	Highly fragmented governmental structure	(31), (49), (56)
32	Slow permits by governmental department and agencies	(1), (2), (17), (31), (32), (35), (49), (51), (56)
33	Excessive time of obtaining permits for laborers	(31), (41)
34	Excessive approval procedures and government policies	(1), (2),(9), (11), (31), (32), (49), (58), (56)
35	High level of variations of regulations among states	(31), (32), (34)
VS6- Immaturity of Legal System		
36	Insufficient law for joint ventures	(31), (34), (43), (49)
37	Lack of independence of the judiciary	(31), (49)
38	High level of changes in law	(4), (11), (31), (34), (43), (51), (56)
39	Existence of corruption	(31), (56)
40	High level of variations of regulations among states	(31), (32), (34)
41	Ineffectiveness of the legal system	(31), (34), (43)
42	Immaturity of legal framework	(31)
43	Lack of coherence of order and justice	(63)
VS7- Restrictions for foreign companies		
44	Strict requirements to obtain work permits	(44), (67)
45	Strict requirement for local partners	(44), (67)
46	Strict requirement of a special residency permit	(67)
47	Strict requirements regarding local tax	(32), (67)
48	Strict requirements to obtain construction license	(67)
49	Import and export restrictions	(33), (44), (61), (67)
VS8- Unavailability of local material		
50	Shortage of material in the host country	(66)

Table 3.9.: (Cont'd)

51	Delay in the approval/manufacture of materials	(8), (17)
52	High level of material delivery problems	(2), (26), (32), (44), (49), (60)
53	Damage of materials in storage	(2), (8), (17), (54)
VS9- Unavailability of equipment		
54	Shortage of equipment in the host country	(66)
55	Delay in the approval/manufacture of equipment	(8), (17)
56	Unskilled Operators	(1), (2), (44)
57	High level of equipment delivery problems	(2), (26), (32), (44), (49), (60)
58	Low productivity and efficiency of equipment	(1), (8), (17), (26)
59	Improper maintenance and lack of spare parts	(9), (17), (32), (66)
60	Requirement of specialized equipment	(32), (44)
VS10- Unavailability of labor		
61	Shortage of skilled labor	(8), (17), (26), (32), (44), (46), (49), (58) (51)
62	High wages of skilled workers	(9), (17)
63	Strict requirements to obtain work permits	(44), (67)
64	High level of labor disputes and strikes	(1), (2), (8), (10), (51),
65	High level of local protectionism	(1), (49)
VS11- Unavailability of subcontractor		
67	Lack of priority of the project	(10), (51),
68	Poor technical skills and experience of subcontractors	(4), (10), (11), (17), (21)
69	Poor quality of subcontractors	(51), (21)
70	Delay in appointing subcontractor	(17), (51),
71	Poor managerial skills of subcontractors	(33), (58) (51),
72	High level of bid variation of subcontractors	(4)
VS12- Unavailability of infrastructure		
73	Shortage in water supply	(19), (49), (61) (62)
74	Unavailability of land and air transportation	(19), (28), (61)
75	Unavailability of water transportation	(61)
76	Unavailability of communication	(19), (61)
77	Unavailability of power	(19), (49), (61)
VS15- Complexity of design		
78	Complexity of plans	(PFE)
79	Complexity of specifications	(PFE)
80	Complexity of shop drawings and samples	(PFE)
81	Technological complexity	(4), (11), (51)
82	Project complexity	(6), (43)

Table 3.9.: (Cont'd)

VS16 - Low constructability		
83	Unsuitable construction methods/changes in method	(17), (44)
84	Poor communication between project management team and design team	(1), (6), (17)
85	High level of technology complexity	(6), (43)
86	Inappropriate project delivery method	(6),
87	Lack of knowledge about location restrictions	(6), (11), (26)
88	Incomplete specifications/design standards and codes	(6), (44)
89	Lack of computer generated models	(6)
VS17 -Complexity of construction method		
90	Complexity of plant and equipment selection	(62)
91	Complexity of project	(6), (43)
VS18- Uncertainty of Geotechnical Investigation		
92	Inadequate/ mistakes in site investigation	(1), (9), (35), (59)
93	High level of site heterogeneities	(32), (59)
94	Measurement inaccuracy and data inconsistency	(32), (59)
95	Lack of proper sampling method	(59) (62)
96	Inadequate in-situ tests or errors in test results	(59), (62)
97	Inadequate laboratory tests	(62)
98	Inadequate site investigation reports	(62)
99	Inappropriate method of site exploration	(62)
VS19- Strict quality requirements		
100	Strict requirements for quality training	(7), (30), (47)
101	Strict requirements for quality assurance and quality control system	(7), (30), (47)
102	Strict requirements for statistical methods	(7), (30)
103	Strict requirements for inspection, testing and information analysis	(1), (30), (47)
104	Strict requirements for supplier involvement	(7), (47), (49)
105	Strict requirements of preparing nonconformance reports	(30)
106	Strict requirements for application of quality control based on foreign specification	(1)
107	Strict requirements of achieving high degree of aesthetics	(30)
108	Strict requirements for company registration with ISO standards	(7), (47)
109	Requirement of appointing quality management staff	(PFE)
VS20- Strict environmental requirements		
110	Strict requirements for prevention of dust emissions	(12), (15), (61)
111	Strict requirements of ISO 14000 series certificate	(12)
112	Strict requirements of environmental management system	(12)
113	Strict requirements for prevention of harmful gases	(12)
114	Strict requirements for prevention of noise	(12), (15), (58), (61)

Table 3.9.: (Cont'd)

115	Strict requirements for prevention of wastes	(12), (15), (58)
116	Strict requirement of complying with international laws about hazardous wastes	(PFE)
117	Strict requirements for threatened or endangered species	(61)
118	Strict requirements to save historic properties	(61)
119	Strict requirements of green building consideration	(PFE)
120	Strict requirements for prevention of light disturbance	(15)
121	Strict requirements for prevention of odors	(15)
122	Strict requirements for an environmental insurance	(15)
VS21 - Strict health and safety requirements		
123	Strict requirements of a special health and safety training program	(13), (27), (32), (58)
124	Strict requirements of safety monitoring and reporting	(13), (27), (32)
125	Strict requirements of inspecting hazardous/dangerous conditions	(13)
126	Strict requirements of well-defined safety organization	(13), (27)
127	Strict requirements of having a company specific safety manual.	(13)
128	Strict requirements related to plant and equipment	(13)
129	Strict requirements of safety signage and warnings at site	(27)
VS22 - Strict Project Management Requirements		
130	Strict requirements of a complicated time management system	(10), (16), (23), (25), (65)
131	Strict requirements of a complicated cost management system	(16), (23), (65)
132	Strict requirements of a complicated quality management system	(16), (23), (25), (65)
133	Strict requirements of a complicated human resources management system	(16), (23), (65)
134	Strict requirements of a risk management system	(16), (23), (25), (65)
135	Strict requirements of a health and safety management system	(25), (65)
136	Strict requirements of a procurement management system	(16), (25), (65)
137	Strict requirements of a communications management system	(16), (25), (65)
138	Strict requirements of a scope management system	(16), (25), (65)
VS23- Vagueness of contract clauses		
139	Lack of standardized contract clauses/formats	(17), (31)
140	Lack of coherence of the contract clauses to the project	(4), (17), (43), (48)
141	Poor definition of rights, obligations and risk sharing among project parties	(4), (14), (34), (43)
142	Poor definition of cost sharing schemes	(14)
143	Poor definition of legalized management procedures	(14)
144	Poor definition of claims and dispute resolution method	(5), (34), (35), (57)
145	Lack of a contractual relationship structure	(5), (31), (49)

Table 3.9.: (Cont'd)

VS24- Contract errors		
146	Inappropriate contractual procedure/ type of contract	(4), (5), (9), (17), (31), (35), (42), (44)
147	Inadequate performance/quality, flaws of contract clauses	(1), (5), (9), (17), (31), (46)
148	Inadequate duration of contract period	(9), (17)
149	Lack of standardized contract clauses/forms	(17), (31)
150	Lack of contract documents	(60)
VS25- Technical incompetency of Engineer		
151	Lack of experience in tendering process	(60)
152	Lack of experience in design process	(16), (32)
153	Lack of experience in construction process	(8), (15), (35)
154	Lack of experience in cost estimation	(16), (32), (35), (58)
155	Lack of experience in resource allocation	(16)
156	Lack of experience in scheduling	(16), (17),(23), (35), (50), (58)
VS26- Managerial incompetency of Engineer		
157	Lack of experience of engineer/newly graduated engineer	(16), (35), (50),
158	Poor Coordination/communication management ability	(2), (10), (16), (17), (58)
159	Poor documentation and delays in approval of documents	(17), (48) (58)
160	Poor problem solving and change management ability	(16), (17), (34),(58)
161	Poor control ability	(17)
VS27- Engineer's Lack of financial resources		
162	Lack of a short-term finance/ Financial status of the engineer	(60)
VS28- Client Unclarity of objectives		
163	Poor, unclear, incomplete definition of scope	(4), (11), (15), (17), (35), (43) (58)
164	Unclarity about project objectives	(60), (66)
165	Unclarity about contract terms	(60), (66)
166	Unclarity about project attributes	(60)
VS29- Client Level of bureaucracy		
167	Excessive and complicated approval procedures	(1), (9), (11), (31), (32), (58) (56)
168	Slow decision-making in the client's organization	(1), (2), (8), (17), (46)
169	Slow permits by client organization	(PFE)
VS30-Client Negative attitude		
170	Bad Reputation of the client	(PFE)
171	Difficulties to arrange meetings	(PFE)
172	Negative attitude towards project parties	(PFE)
173	Poor human resource management and leadership ability	(10), (11), (16), (22), (25), (40), (53), (55),

Table 3.9.: (Cont'd)

		(58)
VS31- Client Poor staff profile		
174	Lack of experience of technical staff	(2), (8), (10), (15), (17), (26), (32), (35), (46), (50)
175	Lack of experience of management staff	(10), (16), (22), (25), (32), (35), (53), (55), (58)
176	Lack of experience of staff within the similar past projects	(21), (35), (50)
177	Lack of education and training of staff	(17), (53), (55)
178	High number of new-graduated staff	(17)
179	Non-realistic organizational structure and work distribution among staff and workers	(11), (17), (22), (44), (46), (55)
VS32- Client Unavailability of financial resources		
180	Lack of a long-term finance	(60)
181	Lack of a short-term finance	(60)
182	Unavailability of funding source from the host government	(61)
183	Unavailability of funding source from lenders or banks	(9), (11), (51), (66) (61)
184	Lack of financial risk identification and mitigation strategies	(66)
185	Unavailability of cash money due to other ongoing projects of the client	(2)
186	Lack of contingency funds for unexpected situations	(48) (58)
187	Lack of an appropriate financial plan	(58)
188	Lack of financial guarantees from project sponsor	(66)
VS33- Client Technical incompetency		
189	Lack of experience in preparation of a project plan	(25), (49)
190	Lack of experience in conducting project feasibility study	(25), (35), (49)
191	Poor cost management ability	(16), (35), (49)
192	Lack of experience in involvement in construction stage	(8), (15)
193	Lack of experience in documentation and approval of documents	(58)
194	Lack of experience in controlling	(60)
VS34- Client Poor managerial/ organizational ability		
195	Poor resource management ability	(2), (11)
196	Slowness in decision making process, giving instructions	(1), (2), (8), (10), (17), (35), (46), (51)
197	Poor coordination/communication management ability	(2), (10), (16), (17), (35), (58)
198	Improper selection system for contractors	(17), (49)
199	Lack of early and continuous involvement to the project	(30), (58)
200	Improper selection of project location, type	(17), (49)
201	Poor problem solving and change management ability	(11), (16), (17), (34), (58)

Table 3.9.: (Cont'd)

202	Poor human resource management and leadership ability	(10), (11), (16), (22), (25), (53), (55), (58)
203	Poor monitoring and supervision of staff/workers	(53), (55)
204	Poor relations with client and related government departments	(4), (16), (31), (43) (49)
VS35- Poor Site Supervision		
205	Lack of a system for monitoring and supervision of staff/workers	(53), (55)
206	Technical incompetency	(8), (15)
207	Poor procurement and quality control ability	(16), (50)
208	Lack of design and construction check	(44), (58)
VS36- Lack of Site Facilities		
209	Lack of transportation systems	(40), (54)
210	Lack of accommodation facilities	(40), (54)
211	Lack of storage places	(40), (54)
212	Lack of administration buildings	(40), (54)
213	Lack of temporary facilities	(54) (62)
VS37- Contractor's Lack of experience in similar projects		
214	Lack of experience in similar type of projects	(PFE)
215	Lack of experience in projects having similar size	(PFE)
216	Lack of experience in projects having similar location	(PFE)
217	Lack of experience in projects having similar construction technology/method.	(PFE)
VS38 - Contractor's Lack of experience in country		
218	Lack of knowledge about general information of the country	(26)
219	Lack of knowledge about governmental structure and political conditions of the country	(67)
220	Lack of knowledge about economic conditions of the country	(67)
221	Lack of knowledge about business and financial conditions	(67)
222	Lack of knowledge about environmental& health & safety regulations	(67)
223	Lack of knowledge about market conditions	(67)
224	Lack of knowledge about the legal framework of the country	(26), (31), (67)
VS39- Contractor's Lack of experience in project delivery system		
225	Lack of knowledge about responsibility sharing between parties	(30), (37), (38)
226	Lack of knowledge about the contracting system of selected PDS	(30), (37)
227	Lack of knowledge about the potential risks of selected PDS	(30), (37)
VS40- Contractor's Lack of experience with client		
228	Lack of knowledge about attributes and past performance of client	(50)
229	Lack of knowledge about attitude and ethics of client	(51)

Table 3.9.: (Cont'd)

230	Lack of knowledge about financial resources of the client	(50)
231	Lack of knowledge about managerial skills of the client	(50)
232	Lack of knowledge about technical competency of the client	(50)
233	Lack of knowledge about tendering/ bidding behavior	(4), (25)
VS41- Contractor's Lack of financial resources		
234	Lack of a short-term finance	(60) (61)
235	Lack of a contract between client and contractor	(66)
236	Unavailability of funding source from lenders or banks	(9), (11), (51), (61) (66)
237	Lack of financial risk identification and mitigation strategies	(66)
238	Lack of contingency funds for unexpected situations	(48) (58)
239	Lack of an appropriate financial plans	(58)
VS42- Contractor's Lack of technical resources		
240	Lack of raw materials	(61)
241	Lack of equipment	(61)
242	Lack of labor	(61)
243	Lack of subcontractors	(61)
244	Lack of utilities	(61)
245	Lack of temporary facilities	(62)
VS43 - Contractor's Lack of staff		
246	Lack of a technical staff	(66)
247	Lack of cost estimator/ planner	(66)
248	Lack of field (site) manager	(60), (64)
249	Lack of procurement engineer	(PFE)
250	Lack of contract administrator	(64) (66)
251	Lack of project controller	(64) (66)
252	Lack of a quality manager	(PFE)
253	Lack of safety engineer	(66)
VS44- Poor project scope management of the contractor		
254	Poor definition of organization requirements	(65)
255	Lack of tools and techniques	(65)
256	Poor project scope definition	(65)
257	Poor scope verification	(65)
258	Poor scope control	(65)
VS45- Poor project time management of the contractor		
259	Poor definition of activities	(42), (65)
260	Poor estimation of activity relationships and durations	(42), (65)
261	Poor estimation of activity resources	(42), (44), (58) (65)
262	Lack of development and control of schedule	(42), (65)
263	Poor judgment and experience of staff	(17), (42)

Table 3.9.: (Cont'd)

264	Unrealistic contract duration	(8), (10), (17), (35), (46)
VS46- Poor project cost management of the contractor		
265	Lack of experience of the cost estimator	(9)
266	Lack of financial control and check, cost reporting and documentation system	(9), (17), (48)
267	Wrong or rigid method of cost estimation	(9), (48) (58)
268	Inaccurate cost estimation	(9), (17), (26), (48) (58)
269	Lack of an appropriate financial plans	(48) (58)
270	Inaccurate quantity take-off	(17), (26), (48)
VS47- Poor project quality management of the contractor		
271	Lack of quality training	(7), (30), (47), (66)
272	Poor quality assurance and quality control system	(7), (30), (47), (66)
273	Poor team work	(7), (30), (66)
274	Lack of statistical data and utilization of statistical methods	(7), (30)
275	Poor supplier involvement	(7), (49), (47)
276	Poor cost of quality measurement	(7), (66)
277	Lack of company registration with ISO standards	(7), (47)
VS48- Poor human resource management of the contractor		
278	Non-realistic organizational structure and work distribution among staff and workers	(22), (46), (55)
279	Poor monitoring and supervision of staff/workers	(53), (55)
280	Lack of providing career development to workers and staff	(22), (55)
281	Poor motivating and building up relationships with staff and workers	(22), (53), (55)
282	Lack of education and training on human resources	(53), (55)
VS49- Poor communications management of the contractor		
283	Poor communication and coordination skills of manager	(9), (10), (17), (21) (65)
284	Poor organizational communication structure	(PFE)
285	Poor communication plan	(65)
286	Poor information distribution	(17), (65)
287	Poor performance reporting	(PFE)
VS50- Poor risk management of the contractor		
288	Lack of risk identification system	(4), (11), (44), (55),(58), (65)
289	Lack of risk assessment system	(4), (5), (44), (55), (58) (65)
290	Lack of risk response system	(4), (44), (55), (58) (65)
291	Lack of risk ownership allocation	(5), (65)
292	Lack of monitoring and reviewing risks	(55), (65)
293	Lack of contingency planning	(44), (65)

Table 3.9.: (Cont'd)

294	Lack of risk training and education	(PFE)
VS51- Poor procurement management of the contractor		
295	Poor selection of appropriate tendering type	(18), (42), (48)
296	Poor selection of appropriate procurement contract type	(18), (65)
297	Lack of a procurement contract	(61), (65)
298	Lack of source selection criteria	(65)
299	Poor procurement methodology	(65)
300	Poor procurement of equipment	(PFE)
301	Poor procurement of materials	(PFE)
302	Poor procurement of labor	(PFE)
303	Poor procurement of subcontractors	(PFE)

3.7. Applicability of Attributes

In order to explore the applicability of the identified attributes, the vulnerability source-attribute framework is further reviewed based the case studies conducted with partner firm experts. The case studies are conducted to collect information and data of construction projects that have been consulted by partner firm experts. These case studies are utilized within two major objectives; evaluation of the applicability of attributes and development of lessons learned database. Firstly, previous projects are reviewed to identify vulnerabilities that initiated the occurrence of risk path scenarios emerged in risk event histories. Then, vulnerability sources of the identified vulnerabilities as well as vulnerability source attributes are explored. To be noted that, the case study approach for the development of lessons learned database will further be introduced in the following chapter of the study. An illustrative example for how the applicability of attributes is examined is given in this section. Although same methodology is carried out for all previous projects, they are not given in this section. However, all other case studies also revealed that the attributes identified through the identification test are meaningful and applicable in real construction projects.

3.7.1. Illustrative Case Study

To illustrate how attributes are extracted through reviews on case studies, reviews on the first project collected from the partner firm experts are given in Table 3.10. The table shows statement of experts, identified vulnerabilities, vulnerability sources and their corresponding attributes along with their ID's.

Table 3.10: Extraction of attributes through review on case studies

Case ID	Statement	Corresponding vulnerability factor	ID	Corresponding vulnerability source	ID	Corresponding Attribute
1.1	"landslides were occurred and caused blockages on the main access road"	Unexpected Events	V21	Natural Catastrophes	VS75	-
1.1	"only road that give access to the construction site"	Adverse Country Related Conditions	V1	Unavailability of Infrastructure	VS12	Unavailability of land and air transportation
1.1	"this was the first project of company"	Contractor's Lack of Experience	V10	Contractor's Lack of Experience in Country	VS38	Lack of knowledge about general conditions
1.2	"client required contractor to procure cement from another cement factory rather than the one determined in the contract clauses"	Client's Incompetency	V8	Client'sUnclarity of Objectives	VS28	Unclarity about contract terms
1.2	"In contract clauses, responsible party from compensation of costs raised due to scope changes were not defined"	Contract Specific Problems	V6	Vagueness of Contract Clauses	VS23	Poor definition of rights, obligations and risk sharing among project parties
1.3	"client's disability to hand-over the construction site and site facilities"	Client's Incompetency	V8	Client's Poor Managerial and Organizational Abilities	VS34	Lack of early and continuous involvement to the project
1.3	"client did not provide plants such as batching plant, crushing plant,	Client's Incompetency	V8	Client's Poor Managerial and	VS34	Poor resource management ability

	required workshops, and construct diversion tunnels”			Organizational Abilities		
1.3	“Lack of plants and delays in the site hand-over”	Adverse Site Condition	V9	Lack of Site Facilities	VS36	Lack of temporary facilities
1.3	“Lack of plants”	Contractor’s Lack of Resources	V11	Contractor’s Lack of Technical Resources	VS42	Lack of equipment
1.4	During the construction process, frequent electricity cuts occurred”	Adverse Site Condition	V9	Lack of Site Facilities	VS36	Lack of temporary facilities
1.4	“frequent electricity cuts”	Contractors’ Lack of Resources	V11	Contractor’s Lack of Technical Resources	VS42	Lack of temporary facilities
1.5	“missing statements in the contract clauses”	Contract Specific Problems	V6	Contract Errors	VS24	Inadequate performance/quality, flaws of contract clauses
1.5	“not recognizing the flaw of contract clauses and carrying out faulty calculations by the client company staff”	Clients’ Incompetency	V8	Clients’ Poor Staff Profile	VS31	Lack of experience of technical staff

CHAPTER 4

METHODOLOGY FOR THE DEVELOPMENT OF LESSONS LEARNED DATABASE

This chapter presents the concept of the knowledge management and methodology for development of the lessons learned database of the risk mapping tool through six sections. The first section overviews the knowledge management concept, classifies knowledge types, introduces its phases and some techniques to implement knowledge management. In the second section, firstly the significance of knowledge management practices in construction industry is introduced, the challenges that plug the way of implementing knowledge management systems within construction companies is explained. Finally, some knowledge management techniques that has been employed in construction industry, is overviewed. Third section introduces the review on literature relating previous learning based risk management approaches in construction projects. In the fourth section, objectives of the development of a lessons learned database within this study, is announced. Fifth section introduces the knowledge management phases employed in the risk mapping tool. Finally, the methodology for the development of the database is explained and an illustrative case study approach is given to show how such a database was established.

4.1. Knowledge Management Concept

4.1.1. Definition of Knowledge

Davenport and Prusak (1998) defined knowledge as “a fluid mix of framed experience, values, contextual information and expert insight”. For Orange et al. (2000), knowledge is the outcome of learning that is pertaining to an individual. Rennie (1999) explained knowledge as 'know-why, know-how, and know-who'. According to Wiig (1993), knowledge involves “truths and beliefs, perspectives and concepts, judgments and expectations, methodologies and know-how”

4.1.2. Types of Knowledge

In current literature, various authors classified knowledge as explicit knowledge and tacit knowledge in accord with the learning source of knowledge. Explicit knowledge can be codified and physically stored in papers or electronic templates that make it transmissible among individuals within an organization (Carrillo and Chinowsky, 2006). Some of the explicit knowledge sources are standard operating procedures, best practice guides for construction industry, (Carrillo and Chinowsky, 2006), human resources data, meeting minutes and the Internet (Patel et al., 2000). According to Zhang et al. (2009), types of explicit knowledge for construction industry are; project information, design drawings and specification, cost reports, risk analysis results and so on. However, tacit knowledge is the intuitive knowledge and expertise gained by the know-how experience or lessons learned of construction experts. It comprises individual beliefs, values, perceptions, and norms (Ozorhon et al., 2005; Patel et al., 2000). Thus, the documentation of tacit knowledge is more difficult and “hard to articulate with formal language” (Patel et al., 2000) and in the case of it will be stored, it requires to be transferred into explicit knowledge (Ozorhon et al., 2005). According to Carrillo and Chinowsky (2006), tacit knowledge can be captured and shared through communication techniques such as face-to-face interviews, lessons learned, etc.

4.1.3. Definition of Knowledge Management

For construction industry, knowledge management is especially facilitated to capture explicit and tacit knowledge associated with the workflow in order to assist decision-makers to acquire, retrieve, and reuse the captured knowledge (Tserng et al., 2009). According to Lin et al. (2006), knowledge management in construction industry is basically, storing and reusing knowledge of past projects for the forthcoming similar projects. In this paper, knowledge management is accepted as; a systematic process of capturing, codifying, storing, retrieving, reusing, and sharing risk event histories gained by know-how experience of construction practitioners by using lessons learned database. However, a number of definitions of knowledge management from a variety of different references are also given in Table 4.1.

Table 4.1: Definition of knowledge management

Definition	Authors
"is the process of creating value from an organization's intangible assets"	Davenport and Prusak (1998)
"the process of systematically and actively managing and leveraging the stores of knowledge in an organization".	Laudon and Laudon (1998)
"deals with creating, securing, capturing, coordinating, combining, retrieving, and distributing knowledge"	(Tserng and Lin, 2005)
"is the explicit contract and management of knowledge within an organization aimed at achieving the company's objective"	Spek and Spijkervet (1997)
"the identification, optimization and active management of intellectual assets to create value, increase productivity, and gain and sustain competitive advantage"	Webb (1998)
" a system that supports the creating, archiving, and sharing of valued information, expertise, and insight within and across communities of people and organizations with similar interests and needs"	Rosenberg (2001)
" is concerned with automating and externalizing explicit knowledge and devising support mechanisms to facilitate tacit knowledge transfer, including creating of knowledge	Benson and Standing (2002)
"refers to the developing body of methods, tools, techniques and values through which organizations can acquire, develop, measure, distribute and provide a return on their intellectual assets"	Kamara et al. (2002)

4.1.4. Phases of Knowledge Management

Kasvi et al. (2003) distinguished knowledge management into four groups of actions: (1) creation of knowledge (i.e. collection, acquire), (2) administration of knowledge (i.e. storage, retrieval), (3) dissemination of knowledge (i.e. transfer within and outside the project), (4) utilization of knowledge (i.e. integration and reuse it in other projects). Lin and Tserng (2003) utilized five phases within the context of knowledge management: (1) knowledge acquisition, (2) knowledge extraction, (3) knowledge storage, (4) knowledge sharing, and (5) knowledge update. Tserng et al. (2009) categorized knowledge management process into five folds; (1) knowledge capturing, (2) knowledge editing and validating, (3) knowledge storing, (4) knowledge sharing, (5) knowledge creating. In this study, the phases of knowledge management that corporate the functions of lessons learned database are accepted as follows; knowledge acquisition and collection, knowledge codification, knowledge storage, knowledge retrieval and reuse, and knowledge share. The contexts of these phases will be introduced in the further sections of this study.

4.1.5 Information Technologies-Integrated Knowledge Management Techniques

In existing literature, various authors discussed the use of information technologies (IT) as a supporting tool for the knowledge management practices. It is widely argued that, the use of IT-tools is essential to implement mechanisms for the collection, representation and transfer of knowledge as well as enhance the benefits of current knowledge management practices. IT tools contribute significant improvement in knowledge storage, access, and reuse (Kıvrak et al., 2008), as well as has a vital importance on the effectiveness of the process of managing knowledge assets (Egbu and Botterill, 2002; Carrillo et al. 2000). According to Tserng et al. (2009), the important component of knowledge management is managing its workflow within the organization, which could be strengthened by incorporation of knowledge management technique with an IT tool.

Laudon and Laudon (1998) classified IT systems that can be used to utilize KM into four folds; those for creating knowledge (knowledge work systems), those for distributing knowledge (office automation systems), those for sharing knowledge (group collaboration systems), those for capturing and codifying knowledge (artificial intelligence system). Al-Ghassani et al. (2005) classified KM tools as ‘KM techniques’ (representing non-IT tools) and ‘KM technologies’ (representing IT tools) that focus on tacit knowledge and explicit knowledge, respectively. Carrillo and Chinowsky (2006) distinguished two major strategies to utilize KM namely; IT-centric strategy and HRM-centric strategy. While IT-centric strategies comprise the use of IT tools to utilize knowledge capturing, accessing and reusing HRM- centric strategy mostly focus on implementing means to encourage knowledge workers to utilize their knowledge.

4.2. Knowledge Management in Construction Industry

The construction industry is a project-based industry where knowledge gained by experience is generated throughout a project lifecycle. Thus, “the construction industry has the potential to benefit from systematic management of knowledge; however, effective mechanisms should be developed, especially for capturing and reusing tacit knowledge”. (Kıvrak et al, 2008)

4.2.1. Importance of Knowledge Management for Construction Industry

Knowledge management has a vital place "within the value chain of an organization" since it can enhance the effectiveness of all major tasks by improved learning ability (Kıvrak et al., 2008). It is widely being acknowledged that, in todays' construction industry, which operates within the dynamic and changing environment, the necessity for knowledge management is arise with the necessity of innovation, enhanced business performance required by the industry, and improved client satisfaction (Kamara et al., 2002; Webb, 1998; Egbu et al. 1999). Zou and Lim (2002) claimed that, implementation of knowledge management and organizational learning within construction companies are needed to assist companies in sustainable continuous improvement especially in competitive and fragmented environment that it operates. According to Shelbourn et al. (2006), an effective knowledge management system has potential to diminish project time and cost, improve quality as well as contribute to take competitive advantage among construction companies. For Falbo et al. (2004) the success and survival of an organization highly rely on its adapting and flexibility competencies, which can only be achieved with utilizing learning. According to Disterer (2002), companies should adapt to store knowledge and experience of current projects for future use in order to deal with the increasing number of technical and social considerations as well as expanding complexity of projects. Cooper et al. (2002) emphasized that, learning from past performance and records enable to learn future management lessons, which enhance the effectiveness of management of projects. In addition, knowledge management support senior management in acquisition and maintenance of project history repositories (i.e. lessons learnt, unique problem handling techniques), thus prevent "re-inventing the wheel", save time and resources (Maqsood et al., 2006). Moreover, it will be not only helpful in carrying out projects successfully, but also for selecting the right project and structuring winning bids (Kıvrak et al., 2008).

In addition, some other authors acknowledged the significance of implementing knowledge management systems when operating in international markets. According to Eriksson et al. (1997), the knowledge about local institutions has a vital place on global companies since this knowledge influence decisions, and assist actions when operating in abroad. According to Johanson and Vahlne (1977), the extent of facing with uncertainties that arise due to operating in a foreign market, is highly depend on the emphasis of organization given to acquiring organizational knowledge. Capturing the knowledge about country, in which global companies operate, can assist companies to reduce knowledge gaps, minimize their ‘liability of foreignness’ and enhance the success of operating in a foreign environment (Lord and Ranft, 2000; Petersen et al., 2008; Zaheer, 2000; Javernick-Will and Levitt, 2010).

4.2.2. Challenges of Knowledge Management in Construction Industry

Although various authors put knowledge management into a vital role, construction companies suffer from a number of reasons to adopt knowledge management as a part of project management practices. The findings of the Kıvrak et al. (2008) revealed that, eight leading Turkish construction contractors that are doing business in international markets are not successful in capturing, storing, sharing and reusing knowledge, or even do not have knowledge management strategies. According to Schindler and Eppler (2003), project amnesia such as lack of capturing and documenting lessons learned can be attributed to the four major reasons; time, motivation, discipline and skills. According to Dikmen et al. (2008), time and budget restrictions, organizational culture, project-based nature, and the type of the knowledge are the major bottlenecks that plug the way of facilitating knowledge transfer by means of post project appraisals. Some common bottlenecks that hinder utilizing knowledge management can be summarized as follows;

Resource constraints: “At the end of the project there is lack of interest or funding to conduct post project reviews” (Mulholland and Christian, 1999; Carrillo et al., 2004). Generally, team members and project organization spread over the company in order to take part in other ongoing project tasks (Kıvrak et al., 2008). Thus, they generally do not have enough time, motivation, or coordination to document and report project reviews and learning after completing a project (Disterer, 2002, Kasvi et al., 2003, Schindler and Eppler, 2003).

Company/ organizational behavior: Companies and individuals are not open to discuss, analyze, and document failures and errors as well as they are often not interested in learning from mistakes (Disterer, 2002, Schindler and Eppler, 2003). “At best, project team members keep the knowledge and experience as individual knowledge, which they may use in the future” (Disterer, 2002). Moreover, project teams do not value old records due to unique nature of the construction industry; therefore, they do not perceive documentation of knowledge as necessary action (Sanvido and Medeiros, 1990; Carrillo et al. 2000).

Improper knowledge management technique/ type of knowledge: The knowledge of construction projects is generally tacit and due to lack of structured systems, the gained knowledge generally could not acquire in an explicit from (Maqsood et al, 2006). “Converting their tacit knowledge to explicit knowledge for the benefit of others is a problem, which is difficult to conduct within a reasonable period and at an acceptable cost” (Carrillo et al., 2000). In addition, “a formal or convenient process does not exist to capture and transfer readily knowledge to subsequent projects” (Ibbs 1986, Mohan 1990). Even though organizations attempt to document the knowledge, they might have difficulty to reuse the documented the knowledge. Schindler and Eppler (2003) listed as some of these reasons as; documenting knowledge too generically or specifically that makes it difficult to understand or achieving the knowledge in a way that people could not retrieve them.

4.2.3. Knowledge Management Techniques in Construction Industry

Dikmen et al. (2008) stressed two major strategies in the context of knowledge management in construction industry; codification strategy and personalization strategy. Codification strategy includes actions of “codifying the knowledge and storing it is databases”, however personalization strategy is much likely related with the sharing the knowledge only by personal interaction. According to Newell et al. (2006), acquiring the “lessons learned” is the common strategy for the transfer of knowledge among projects. Although, companies mostly facilitate post-project appraisals and project review practices to capture, store and transfer the lessons learned in a project, in their study Dikmen et al. (2008) discussed the major drawbacks of facilitating these appraisals in the knowledge transfer among projects. The study of Schindler and Eppler (2003) is another attempt for the classification of techniques for the development of past project histories. Authors examined these techniques under two folds, process-based methods, and documentation-based methods. The first method is about the capturing the lessons learned from the completed projects by conducting “project review/project audits, post-control, post-project appraisal, and after action review.” Documentation-based methods incorporate immediate capture and collection of experiences when they occur. Micro articles, learning histories and RECALL are the some techniques that can be facilitated in this approach. The term “lessons learned” is generally recommended in the available construction engineering and management literature to facilitate management of knowledge within project and organizational levels. Schindler and Eppler (2003) defined lessons learned as “key project experiences which have certain general business relevance for future projects. They have been validated by a project team and represent a consensus on a key insight that should be considered in future projects". In existing literature, several authors have been suggested to capture "lessons learned" in order to improve effectiveness of risk management process. For instance, Tserng et al. (2009) and Dikmen et al. (2008) suggested the use of lessons learned database to facilitate learning from risk events and corporate risk memory in which risk information and lessons learned regarding the factors affecting risk consequences of previous projects are stored.

4.3. Literature Review on Previous Knowledge Management Approaches

In literature there is a consensus that organizations should establish a lessons learned system to learn with their own experience as well as to acquire, evaluate, review, share and reuse knowledge gained from completed projects which otherwise can be resulted in reoccurrence of mistakes.

Within the context of demonstrating how learning-based risk management can be achieved in practice, Dikmen et al. (2008) developed a tool that is used to construct a lesson-learned database. The database enables to define access, store, and update risk-related information (vulnerability, risk sources, risk event, and consequences) throughout the project lifecycle. Post project risk event histories exemplified in the study of Dikmen et al. (2008) are given in Figure 4.1.

RBS code	Risk source	Risk event	Cost impact ($)	Time impact (months)	Final impact (1–5 scale)	Vulnerability
02.09.04.00	Bureaucratic delay	Due to delay of expropriation, site handover was delayed.	1,000,000	3	5	Strategy used to minimise the risk of delay was acceleration. Although the project is finished on time, due to vagueness of contract about acceleration, cost compensation was not possible. It is a claim issue.
03.02.01.00	Geological conditions	After cut-off wall was constructed, it was realised that a certain portion of the wall could not reach the bedrock. The wall had to be reconstructed to reach the original bedrock.	1,500,000	4	5	The cut-off wall machine was sent to the home country as soon as the cut-off wall construction was over. When rework was required, it had to be brought back resulting in extra cost and delay. Client insists that the geological risk had to be foreseen by the contractor. It turned out to be a claim issue.
02.02.01.00	Vagueness of contract clauses	The price difference due to change in exchange rates and construction price indices could not be claimed because the escalation formula in the contract was vague.	1,000,000	No impact on time	4	The escalation formula had two parts. The second part of the escalation formula gave a negative value for a specific period of time. It is clearly stated in the contract that the minimum value for the first part should be taken as zero, if it is negative. But a similar condition for the second part was not specified. Client made deductions rather than escalation. This is a claim issue.
02.09.05.00	Change orders	As a result of client's change orders, the quantities increased but the payments regarding the increased quantities were done using unit prices of the government, not based on the lump-sum amount.	500,000	No impact on time	4	The interpretation of lump-sum contract in the Turkish practice is different than the general practice. If the quantities are less than the reservation amounts, the deductions are made based on the lump-sum prices, if they increase, additional part is paid using unit prices of the government. The unit prices were significantly lower than the lump-sum prices.

Figure 4.1: Post project risk event histories (Dikmen et al., 2008)

Zou and Lim (2002) proposed an organizational learning integrated knowledge management model that comprised of five consecutive steps; knowledge planning, knowledge organizing, knowledge implementing, knowledge controlling and knowledge evaluating. Kıvrak et al. (2008) developed a Web-based system called "Knowledge Platform for Contractors (KPfC) to utilize knowledge capturing in construction projects in order to be reused in forthcoming projects. The system allows capturing tacit knowledge such as; know how, innovations and expert recommendations as well as explicit knowledge such as; documents and reports. Mulholland and Christian (1999) suggested a systematic risk assessment approach to define and quantify uncertainty involved in construction schedules. The computer-based system incorporates a HyperCard risk identification module to store knowledge acquired from experts associated with the previously occurred schedule risks. Tserng et al. (2009) proposed an ontology-based risk management framework (ORM) and a risk ontology development model to utilize knowledge extraction, and reuse in the course of risk management. Based on the framework, authors also developed an IR algorithm-based ontology extraction tool to support the risk ontology. Lin et al. (2006) proposed "Network Knowledge Maps" that captures the knowledge gained in construction phase of projects as well as demonstrates relations among the captured project knowledge. Based on the network knowledge maps, authors developed a "Map-Based Knowledge Management" system that enables construction experts and engineers to retrieve, share and reuse past project knowledge and experience for forthcoming similar projects. Figure 4.2 represent the underlying theory of the knowledge management system applied by Lin et al. (2006).

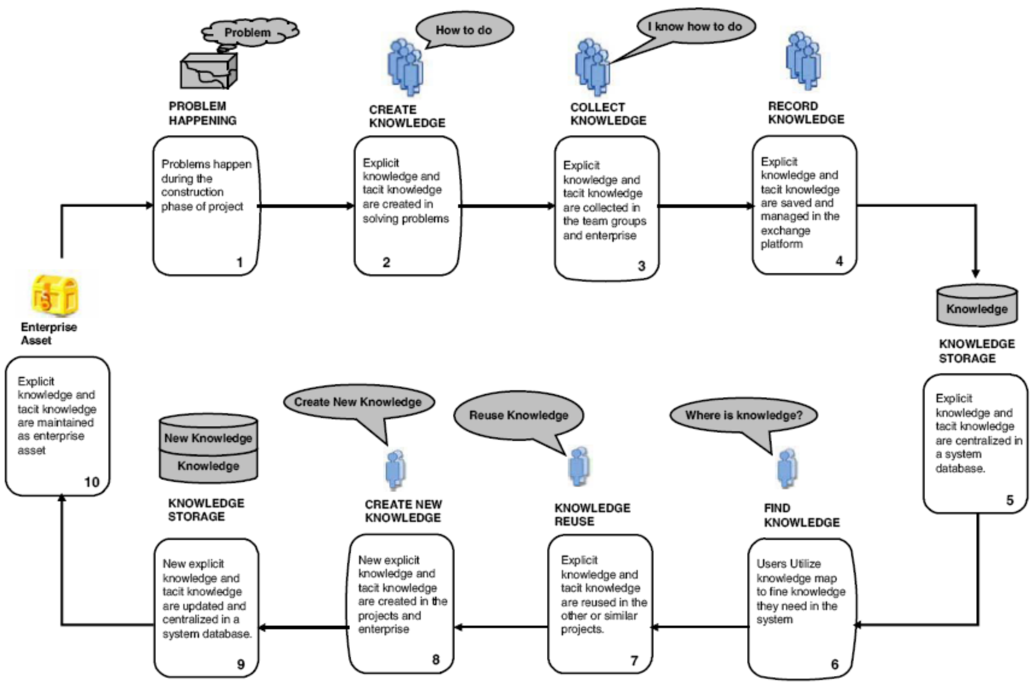

Figure 4.2: Knowledge management phases (Lin et al. 2006)

Falbo et al. (2004) conducted an ontology-based knowledge management approach to supplement organizational learning in risk management practices. Within this context, authors developed a knowledge management-based tool, GeRis, in which knowledge items are codified by ontological tags for the knowledge retrieval purposes. The tool was supported by the Ontology-Based Software Engineering Environment (ODE) and facilitates knowledge management infrastructure of ODE. The KM infrastructure of ODE employed by Falbo et al. (2004) is given in Figure 4.3.

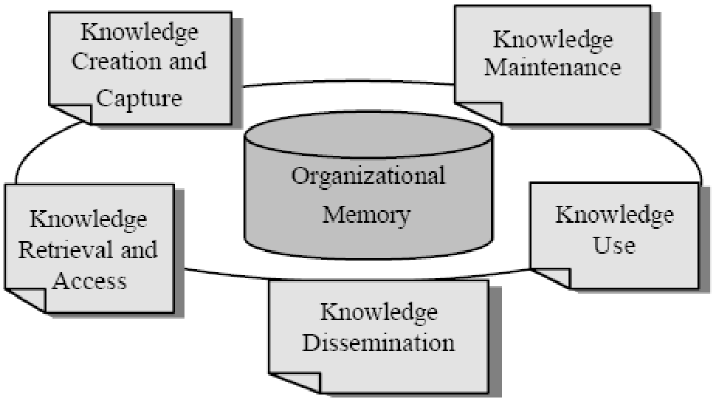

Figure 4.3: Knowledge management infrastructure (Falbo et al., 2004)

Leung and Chuah (2008) developed a computerized knowledge-based system (KBS) that aid decision-makers when identifying and assessing project risks. With the consideration of causalities among risk factors, authors employed a risk identification model that would be used to acquire, capture, and represent the knowledge of previous experiences. KBS is formed by two major modules; a knowledge base in which knowledge of problem factors, rules and concepts are stored, and an inference engine which works as a knowledge processor. Figure 4.4 demonstrates the architecture of the risk identification knowledge-based system employed by Leung and Chuah (2008).

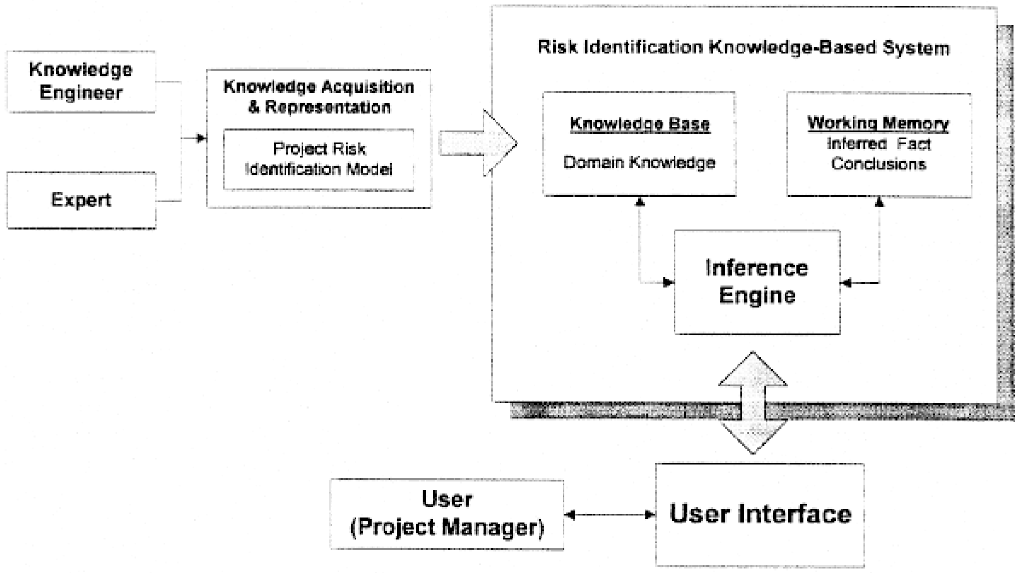

Figure 4.4: Architecture knowledge-based system (Leung and Chuah, 2008)

Maqsood et al. (2006) discussed the value of knowledge management in development of project histories that aid the transformation of an organization into a learning organization. Authors used a systems approach, soft system methodology (SSM), to demonstrate project history concerns of an Australian construction company, to draw the overall picture of the underlying process and discuss activities of the conceptual model. The conceptual model of project histories developed by Maqsood et al. (2006) is given in Figure 4.5.

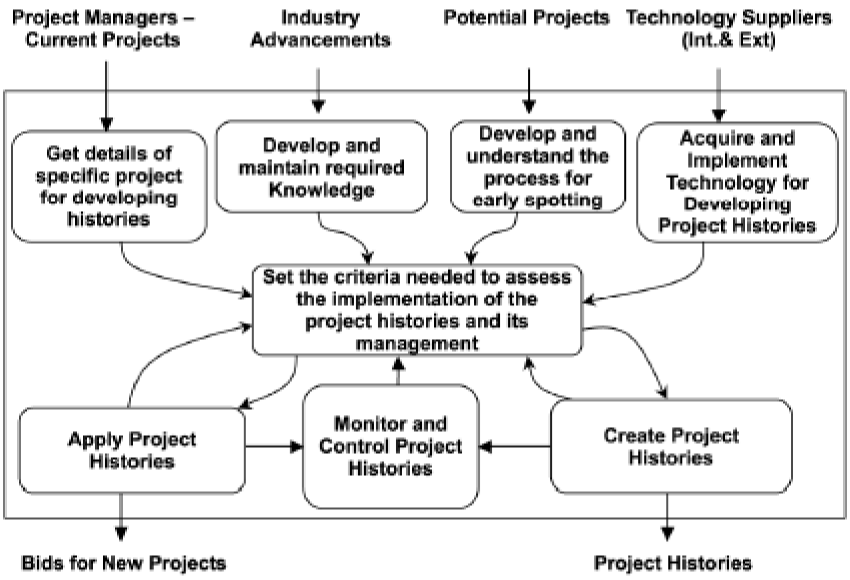

Figure 4.5: The conceptual model of project histories (Maqsood et al., 2006)

4.4. Objectives of Development of Lessons Learned Database

The discussions within the available literature revealed that, construction stakeholders are not familiar with risk assessment techniques except checklists based on intuition/judgment and experience. In addition, due to the unique characteristic of construction projects, there is generally lack of verified or commonly accepted data to quantify risks, which in turn lead risk assessment outcomes to rely on subjective judgments. According to Dikmen et al. (2008), another major bottleneck in quantifying the magnitudes of risk factors in future projects is the lack of recording the circumstances under which outcomes of previous projects are occurred. Thus, decision makers cannot learn from past due to unavailability of interrelations among risk factors and outcomes of past project. Kasvi et al. (2003) added that, in case of the lessons learned from previous projects are not recorded for future use, it is hard to understand what happened and why.

In this study, lessons learned database is established to develop a risk memory in which risk event histories of past projects as well as their triggering risk-related information are stored. Database also enables the retrieval of knowledge of past projects in accord with their risk information in order to reuse it in a forthcoming project. In this thesis, the objective of capturing the knowledge gained from past projects through a lessons learned database are within two main folds; facilitating “learning from risks” to enhance the risk assessment process, developing organizational risk memory that may improve organizational learning.

4.4.1. Assisting in Risk Assessment Process

It is argued that learning from risks may assist decision-makers in the risk assessment process. Within the context of the methodology, inputs for the risk assessment are solely the magnitudes of the vulnerability sources that should be defined by decision makers. Decision makers can enhance their preferences on the magnitudes of such sources by learning from risks that are retrieved from the database. In this thesis, learning from risks refers to the following process; retrieving similar previous project records from database, that are occurred due to the matched vulnerability source, discussing past project records and experiences, and finally assigning a rating to the related vulnerability source by comparing current project conditions with the previous one. The expected benefits of facilitating “learning from risks” while assessing the magnitudes of vulnerability sources are identified and discussed under the following topics;

Realistic forecasts about future projects: Risk event histories of previous projects may aid to forecast what is likely occur in the similar forthcoming projects. 'Lessons learned' allows the representation of variations among planned and actual tasks that were experienced in previously finished projects by giving information about 'what was planned' and 'what actually happened. Same issue is also discussed in the study of Dikmen et al. (2008). Authors proposed that, learning from risks might aid in developing more realistic risk management approaches as well as assist in making "more informed forecasts about future projects". Moreover, in some conditions risk events that happened in previous projects might reoccur in similar forthcoming projects. As was stressed by Niwa (1989), especially large construction projects are more vulnerable to the reoccurrence of previous similar events resulting unfavorable consequences. Authors argued that learning from previous projects is a success factor for this type of projects. In this study, it is argued that, although the projects' inner characteristics (vulnerabilities) determine in what extent the project will be affected with the occurred risk events; recording the risk event histories at least can give an idea about in what range the occurred risk events may result in the known risk consequence. In other words, the knowledge about what type of risk events were occurred, what were their severity and how they affected the severity of the risk consequence of a previously finished project, can improve the effectiveness of initial predictions about the current project. For example, existence of 'client's incompetency' can result in occurrence of 'lags in cash flow' (risk event) which in turn result in high severity of 'cost overrun' (high severity contributed to the rating 4 in Likert scale) in a previously finished project. Based on the knowledge of previous project, in a forthcoming project, it can be likely predicted that occurrence of 'lags in cash flow' can highly lead to additional costs; however, competency level of client of the forthcoming project should still be considered.

Examination of own circumstances under which risks occurred: According to Dikmen et al. (2008), acquiring risk event histories with considering vulnerability sources can enhance the knowledge share among projects as well as may reduce risks severities in the case of the effects of vulnerabilities are reduced in the forthcoming projects. Within the context of above-mentioned example, occurrence of 'lags in cash flow' is influenced by the competency level of client; however, the managerial skills of contractor as a vulnerability also controls the occurrence of cash flow problems. For example, from a previous project case that is acquired in database, it is known that contractor (decision-maker himself) did not carry out project cost management effectively and client was poor in preparing financial plans and financing the project, all which resulted in cash flow problems when operating the project. When the same contractor conducts risk assessment at the beginning of a forthcoming project, the knowledge of previous project may provide him to avoid the risk of 'lags in cash flow'. Even though, the vulnerability of 'client's incompetency' cannot be reduced, by possessing competency on cost management or implementing managerial strategies, contractor can minimize the effect of 'contractors' lack of managerial skills' in some extent which in turn reduces the risk of 'lags in cash flow'. In the case of contractor reduced the effect of vulnerability which is about his managerial skills, he can predict that in a forthcoming project, 'lags in cash flow' may not have same severity as was in previous project.

Predictions about risk path chains of future projects: Numerical data's generally answers "what", "where" and "how many" questions; however they could not explain critical "why" and "how" questions, which are better explained by reports, case studies, and stories Schindler and Eppler (2003). Knowledge based systems could aid project managers in managing risks effectively and making judgments easier by demonstrating "what was happened and why" in previous experiences (Robinson, 1988). Rather than recording solely simple facts (risk events), demonstrating the triggering factors for the occurrence of these facts as well as representing consequences of them are crucial steps to gain in-depth understanding of the circumstances of forthcoming projects. As was pointed out by Dikmen et al. (2008), even though risk events might be unique to each project, similar risk variables and vulnerabilities exist in all projects. Moreover, the generic risk path chain (vulnerability-risk source- risk event- risk consequence) is mostly be applicable to all project conditions which enables share of risk-related information among projects (Dikmen et al, 2008). For example, when carrying out risk assessment of a project, decision-makers can forecast that time involvement in getting permits may be excessive in the case of country possess high level of bureaucracy. However, having a knowledge about actually occurred risk event such as 'due to high level of bureaucracy imposed by governmental departments, getting permits to import construction resources took considerable time which resulted in one month delay in construction works' can provide in-depth understanding about probable problems that may emerge due to high level of bureaucracy involved in a country. Within this context, past project cases are recorded in database in accord with their following risk-related information; "what has happened (risk events)", "what are the reasons of this happening (risk sources)", "the innate characteristics or triggering factors of these reasons (vulnerabilities)" and "what is the result of this happening (risk consequence)". Thus, figuring out interrelations among risk-related variables as well as constructing previous risk path chains may enhance predictions of future projects. So, questions of "how a certain circumstance may result in which risk event" or "what might be the consequences of the occurred risk event" of decision makers might be answered.

Incorporation of experiences of several decision-makers: By definition, experiences are "bound to people who are personally involved in the corresponding problem solving processes" (Schindler and Eppler, 2003) and generally could not be accessible with other people and facilitated during any course (i.e. risk assessment) of a project. However, the preferences of single decision-maker on the inputs of an assessment process can bring high level of subjectivity to the assessment outcomes. In addition, experiences of single decision-maker can be limited or not sufficient (Yeo, 1990) which may lead to carrying out assessment processes incompetently. Thus, the incorporation of experiences of several decision-makers to the database is necessarily required to enhance the development of a more comprehended risk memory (Yeo, 1990) as well as the utilization of risk assessment process. In this study, it is argued that, subjectivity involved in the risk assessment outcomes may be decreased in some extents through collaborating experiences of several decision-makers during the quantification of magnitudes of the vulnerability sources. In addition, using the knowledge-based risk mapping tool, inexperienced project team members could accomplish risk assessment process through facilitating organizational knowledge and experiences regarding risk event histories stored in the lessons learned database.

4.4.2. Development of an Organizational Risk Memory

Stein and Zwass (1995) define organizational memory as " the means by which knowledge from the past is brought to bear on present activities". According to Conklin (2001), organizational memory transforms into a corporate assess that is developed by collecting, organizing, transferring, and reusing knowledge by its employees.

In this study, it is argue that collection, storage and maintenance of the project history as a company level rather than individual experience can be an encouraging effort to structure an organizational memory. Organizational memory assist in maintaining knowledge for future use by storing in a system, which otherwise would be lost. In addition, storing past information and knowledge of an organization can assist to bear on present decisions and tasks. (Walsh and Ungson, 1991; Stein and Zwass, 1995) Moreover, "in project-based industries like construction, continuity in knowledge transfer from project level to enterprise level is required for an efficient organizational learning" (Dikmen et al. 2008). Within literature, several authors emphasized the importance of incorporation of company memory in which past projects are stored and documented. The expected benefits of facilitating organizational learning by development of an organizational risk memory are discussed under the following topics;

Prevention of reoccurrence of mistakes: Capturing and documenting the project experiences enables a company the comparison of its various projects in a systematic and rational manner. According to Javernick-Will and Levitt (2010), in case organizations do not have learning and sharing mechanisms, organizations may spend time and resources due to reoccurrence of the same mistakes or "reinventing the wheel". By capturing knowledge of previous projects, mistakes and probable pitfalls of previous operations can be collected and documented. In addition, the design of database allows capturing cause and effect relations of risk event histories rather than acquiring the simple and obvious fact about the history. Thus, triggering factors for the occurrence of risk events, vulnerabilities inherit in the project environment, solutions or mitigation strategies that are implemented to reduce the severities of risk events can be acquired in the form of knowledge of past project cases. By examination of causality among previous risk events, reoccurrence of mistakes can be minimized or at least appropriate mitigation strategies can be implemented.

Prevention of knowledge loss: The organizational memory is the "intellectual capital of an organization" (Wetherill et al., 2002) and one of its major constituent is the personal knowledge (Ozorhon et al., 2005). However, there exists always a risk of loss of personal knowledge (Ozorhon et al., 2005). This is due to fact that; in real applications and in literature, the gained experiences and knowledge are generally captured and gathered after the completion of the project (Schindler and Eppler, 2003). However, generally project team members often spread over the company and take part in new projects after completing the required tasks within a project. They keep the gained experiences with themselves and unless they have been documented, they can be accessible only with informal networks (Schdinler and Eppler, 2003). In addition, through retirement or resignation of project experts and managers, the gained knowledge and lessons learned could be lost if not captured or shared properly (Leung and Chuah, 2008; Kıvrak et al., 2008). According to Kıvrak et al. (2008), effective knowledge management practices are essential for construction companies in order to avoid loss of knowledge that gained throughout a project. The proposed database in this study allows continuous capturing and storing risk events that have been occurred throughout project’s progress. Thus, rather than a single post-project review, capturing gained knowledge instantly enhances the effectiveness of quality of knowledge (i.e. occurred risk events are more recent) as well as easiness of assembling team members in knowledge acquisition process as they are not dispersed yet.

Enhancement in organizational learning: According to Ozorhon et al. (2005), development of an organizational memory is a significant action involved in knowledge management practices since it utilizes organizational learning process. Nonaka (1998) defined organizational learning as interplay among personal learning that generates knowledge within an organization. Patel et al. (2000) and Carrillo and Chinowsky (2006) perceive organizational learning as an ability of an organization which can capture, share and reuse knowledge in order to adopt changes, improve performance and sustain in competitive environment. The study of Maqsood and Finegan (2003) revealed that, utilizing learning from knowledge assists organizations in developing the internal knowledge (i.e. past project histories of organization), enhances the integration and interrelations among people, process and technology involved within an organization as well as narrows the knowledge gap between external sources (i.e. academic research) and organizations. In this study, an automatic report generation system is incorporated within the database that allows knowledge sharing among individuals throughout the organization which provides not only learning from own experiences that are limited and personal, but also learning from experiences of other team members.

4.5. Knowledge Management Phases Employed by the Lessons Learned Database

Lessons learned database facilitates five consecutive knowledge management steps namely; knowledge acquisition, knowledge codification, knowledge storage, knowledge retrieval and reuse, and knowledge transfer. The knowledge-based processes utilized by lessons learned database is given in Figure 4.6. How the lessons learned database is developed and how knowledge management phases can be facilitated, will be introduced in the further sections of this study. However, in this section, an overview of the knowledge management phases is given in order to introduce the content and the significance of each phase.

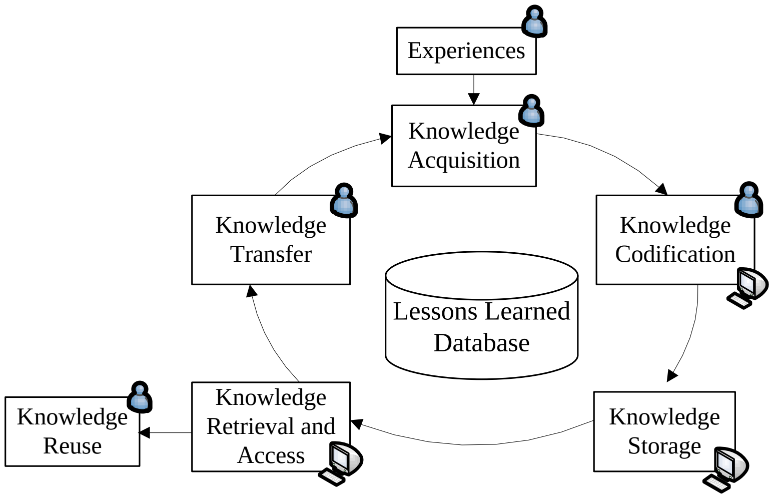

Figure 4.6: Knowledge management processes in lessons learned database

Step 1: Knowledge Acquisition

In this study, knowledge acquisition refers to the collection of know-how experience and lessons learned knowledge gained by construction practitioners' throughout a project lifecycle. Although knowledge acquisition can be extended to involve 'digital records', 'virtual communication and collaboration' and etc. (Lin et al., 2006), in this study only the verbal statements of construction experts regarding their past project experiences are captured and recorded in the acquisition step. This step is based on the collection of information and risk event histories of previously finished project. Project information involves data about previously completed project such as duration, contract type, payment type, or role of company in the project. In addition, risk event histories are the verbal statements that describe 'what actually happened in the project', 'why did they happened', or 'what was the consequence of their occurrence'.

Step 2: Knowledge Codification

Knowledge codification accepted as codifying and documenting the captured knowledge into the database. According to the Newell et al. (2006), the type of knowledge acquired in lessons learned databases determine the success or failure of such databases. In order to enhance a successful learning-based databases, capturing the simple and obvious facts resulting in the project consequences (what was done) is solely insufficient, reasons for the occurrence of these consequences (why and how) should also be acquired (Williams, 2008;

Newell et al., 2006). In addition, in practice the relations among risk consequences (that are formed through the occurrence of risk events) and risk events depend on the influence of project vulnerabilities (i.e. company factors, project characteristics) (Zhang, 2007). Thus, the process of learning from risks should capture the "lessons learned about project vulnerability" (Dikmen et al, 2008). In this study, the captured knowledge in the knowledge acquisition step, is reviewed in order to identify causalities among the risk-related variables (i.e. vulnerability, risk source, etc.) emerged in captured knowledge as well as to codify the captured knowledge in accord with the identified risk-related variables. The detailed process of knowledge codification will further be introduced in the following section of this chapter.

Step 3: Knowledge Storage

In knowledge storage phase, the gained knowledge and information are administrated and stored in the database**.** The study of Kıvrak et al. (2008) revealed that, even though knowledge is stored, excessive time consumption in finding the stored knowledge is the one of the main reason behind the preference of decision-makers on facilitating own intuition and experience. Thus, a user-friendly database is necessary to eliminate the excessive time involvement in knowledge retrieval process. It is argued that, although the captured 'lessons learned' should be stored in a database (i.e. in this study, it is called as case library), the database should be designed in a way that, decision makers will not be have to find the knowledge by examining each knowledge documents one by one and manually. In accord with this context, past project cases are decided to be stored in database by their codified risk-related information tags so that they will be retrieved automatically when they are needed. For example, when carrying out risk assessment process, the stored knowledge can be retrieved based on their codified tags automatically by only clicking on the relevant button (it will be introduced in further section) which avoids excessive time and effort involved in knowledge retrieval phase.

In addition, De Zoysa and Russell (2003) argued that the failure of most of the knowledge-based risk management systems could be attributed to their incapability of requiring characteristics and attributes that represent the context of the projects. However, project attributes have a vital place on analyzing the project histories since they can solely influence the occurrence of risk events. For example, facilitating in international markets bring additional risks due to operating in a foreign environment and participating with people from diverse cultures. Although, risks related with the country related conditions can emerge in each country, their probability of occurrence and the severity of the occurred risks can be varied. For example, 'instability of economic growth' can have a significant magnitude in developing or undeveloped countries however it may not be the case in developed ones. Thus, while tool retrieves the past project histories, it will also retrieve project attributes in order to effectively compare current project with the previous one based on project circumstances.

Step 4: Knowledge Retrieval

Knowledge retrieval phase refers to the representation, access and transfer of knowledge items for reuse purposes by all experts, engineers or other project practitioners who need to retrieve any required knowledge. According to Tserng et al. (2009), knowledge reuse and knowledge share within the organization is an important subject about the performance of risk management since construction industry in its nature comprise huge and complex project data. In addition, utilizing knowledge acquisition is not sufficient for companies that are operating in a project-based industry and in an international market, and the flow of knowledge among organization members should needed (Nissen 2007). However, Woo et al. (2004) claimed that, although construction companies have been successful in knowledge acquisition and storage, they are poor in knowledge retrieval and share. This can be attributed to the lack of mechanisms to retrieve the stored knowledge or lack of knowledge about when and how to use the retrieved knowledge. In this study, it is attempted to use the retrieved knowledge in risk assessment process and it is addressed when or how to use it. The database will be used when decision-makers assign vulnerability source ratings in risk assessment process. The database allows the retrieval of stored knowledge (project cases) in the case of similar cases have been happened due to the same vulnerability source. As a remark, database automatically selects and retrieves previous project knowledge that has been codified in database in accord with the matched vulnerability source. Thus, the retrieved knowledge can be reused by decision-makers in assigning ratings of vulnerability sources of current project based on the information of similar previous project.

Step 5: Knowledge Transfer

The study of Ozorhon et al. (2005) revealed that, although construction practitioners perceive knowledge sharing and transfer as the most significant activity, these activities generally could not be facilitated effectively. However, according to Patel et al. (2000)

creation of knowledge is itself could not satisfy the needs of organizations and it has to be shared, indeed it is the initial aim of knowledge management practices. In this study, knowledge transfer refers to the share and dissemination of previous project cases throughout an organization. The development of database by accumulation of risk event histories proceeds by two flows; by sharing and transferring knowledge (project cases) within the organization, and capturing knowledge into the database after completing a task or a project by decision makers. Within this context, in order to make the stored knowledge accessible, an automatic report generation system is developed that documents the stored past project cases within the database. Thus, who needs the stored knowledge can easily document it with the use of report system. In addition, by sharing the knowledge throughout the organization, it is aimed to assist organizations in utilization of organizational learning. With the use of automatic report generation system, individuals can access to others' experiences and make them use in forthcoming projects.

4.6. Case Study Approach for the Development of Lessons Learned Database

Using the risk-vulnerability ontology as basis and capturing partner firm experts' knowledge about risk events, an initial lessons learned database framework was built. As a secondary consideration, the phases of knowledge management given in the previous section build the underlying methodology for the development of the database. This approach consists of: (1) collecting past project experiences from partner firm experts, (2) reviewing the collected experiences and extracting risk-vulnerability parameters (3) codifying these experiences based on the extracted parameters, (4) storing past experiences in the form of project cases within the lessons learned database (5) retrieving past project cases based on their matched vulnerability sources during the risk assessment process. The steps of research methodology for the development of lessons learned database are given in Figure 4.7.

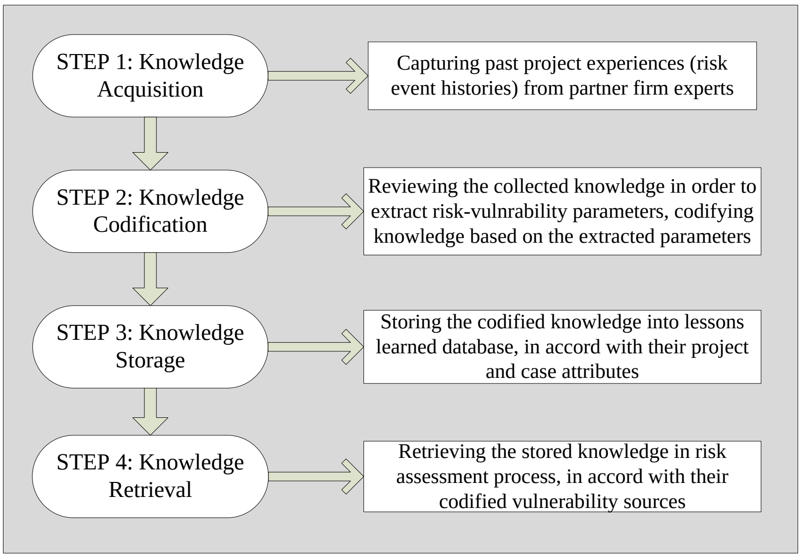

Figure 4.7: Methodology for the development of lessons learned database

Several interviews are conducted with the partner firm experts during the collection of the project histories and several sessions are held to review collected histories within the above-mentioned methodology. The findings of these interviews and sessions were reported in Appendix-B. However, conducted steps to develop lessons learned database framework was discussed and an illustrative example was provided in this section to demonstrate how risk factors are extracted from real project cases.

Several interview meetings took place with the partner firm experts to collect and acquire knowledge and practical experiences (real risk event histories) gained in their previous projects. “Since most know how, know what, and experience exist in the minds of people, capturing tacit knowledge of experts and engineers involved in projects and reusing in future projects is critical for the companies” (Tserng and Lin, 2005; Woo et al., 2004). In order to enhance the benefits of knowledge acquisition, a systematic methodology is employed to capture ‘know how’, ‘know what’ and experiences of partner firm experts. Within this context, experts were interviewed with the previously structured set of questions that have emerged from discussions about which type of knowledge/information/data are necessary to structure the database. These questions are divided into three sets: ‘knowledge about project’, ‘knowledge about case’, ‘knowledge about case attributes’. The structured questions assisted to capture tacit knowledge of experts in the framework of ‘add a new case’ function employed in the tool. These questions along with their verbal definitions are given in Table 4.2. As a remark, the framework of ‘add a new case function’ of the tool will be introduced in fifth chapter of this thesis.

Table 4.2: Set of questions for knowledge acquisition process

Question set	Question	Definition
Knowledge about project	Q1.What were the information/attributes of the project.	Asks to define project information such as country name, project type, contract type, etc.
Knowledge about case	Q2.What actually happened in the project.	Asks to describe lessons learned that gained when operating the project.
	Q3. How the project objectives varied and in what extent.	Asks to define risk events emerged from the lessons learned.
	Q4. What were the reasons that triggered the occurrence of these events.	Asks to define risk sources resulted in occurrence of risk events.
Knowledge about case attributes	Q5. How company conditions or project circumstances triggered the occurrence of risk events.	Asks to define vulnerability of the project or the company to the risk event.
	Q6. Why these conditions or circumstances exist.	Asks to define sources of vulnerabilities.
	Q7. How the occurred risk events affected the project.	Asks to define consequence(s) of risk events such as cost overrun, delay, suspension, etc.
	Q8. In what extent these events resulted in the specified consequence.	Asks to evaluate the severity of case consequence.

The information emerged from the answers form the basis of the collection of past project histories. The acquired knowledge from the partner firm experts will further be reviewed in order to codify and store knowledge in the database. Thus, to maintain the speech of experts as well as to investigate and review it in detail, the experts are requested for permission to audiotape the meeting sessions. At the end of these sections, 32 different risk events (project cases) from 13 real construction projects were collected and stored in the prototype lessons learned database. Table 4.3 shows the profiles of the acquired projects; project budget, project year, project duration, project country and project type. Captured cases from the acquired projects along with their case name, are given in Table 4.4.

Table 4.3: Profile of collected projects

Project ID	Duration	Year	Country	Budget	Type
1	50 months	2002	Turkey	150.000.000 €	Hydro Electrical Power Plant
2	30 months	2009	Kazakhstan	50.000.000 $	Housing
3	20 months	1982	Libya	10.000.000 $	Housing Project
4	45 months	2003	Latvia	35.000.000 €	Housing, business center
5	36 months	1997	Turkey	80.000.000 ₺	Housing
6	24 months	2010	Turkey	70.000.000 €	Shopping mall
7	24 months	1975	Turkey	25.000.000 ₺	Housing
8	26 Months	2004	Poland	30.000.000 €	Fast Train
9	33 months	2009	Azerbaijani	75.000.000 $	Housing
10	20 months	2010	Turkey	45.000.000 €	Shopping mall
11	20 months	2000	Turkey	18.000.000 €	Housing
12	24 months	1992	Russia	45.000.000 $	Housing
13	12 months	1997	Turkey	55.000.000 $	Light Rail System

Table 4.4: Profile of captured project cases

Project	Case Id	Case Name
1	1.1.	Occurrence of landslides
	1.2.	Missing contract statement
	1.3.	Delay in site hand-over
	1.4.	Electricity cuts
	1.5.	Wrong application of escalation formula
2	2.1.	Strict requirement for local partner
	2.2.	Strict requirements to obtain work permits
3	3.1.	Strict requirements to export construction material
	3.2.	Theft of construction equipment
4	4.1.	Strict fire precaution requirements
	4.2.	Poor staff profile of client company
	4.3.	Conflicts among subcontractor and project manager
	4.4.	Occurrence of economic crisis
	4.5.	Unavailability of local material
	4.6.	Theft in site storage area
5	5.1.	Poor site investigation
	5.2.	Conflicts among design specifications
6	6.1.	Poor performance of subcontractor
	6.2.	Complexity of design
	6.3.	Poor communication among teams
	6.4.	Incompetent planning team
7	7.1.	Rehabilitation of foundation
8	8.1.	Problems in obtaining tree-cutting permits

Table4.4: (Cont'd)

	8.2.	Changes in type of the construction material
	8.3.	Uncertainty of soil type
9	9.1.	Defects in frame components
	9.2.	Tight project schedule
10	10.1	Unclarity of standards and specifications
11	11.1	Conflicts among municipality and contractor company
12	12.1	Shortage of fresh water
13	13.1	Changes in design
	13.2.	Inflation in material prices

Within the context of the knowledge codification phase, for each project, the experts in the partner firm were requested to give some information about the risk events occurred in the project, the factors that triggered the occurrence of these events, consequences of this events as well as their impact on the overall cost overrun of the project. Within the case review process, firstly the triggering factors that initiate risk paths of the case (vulnerabilities of the related project) are identified. As a further attempt, the reasons for the occurrence of the risk events, that are adverse changes or unexpected events, which cause the project environment to be exposed to bad happening, were specified. These adverse changes or unexpected events are the collections of the risk sources of the related project case. In addition, the sources of the identified vulnerabilities are also determined and each project case are codified and stored in database in accord with assigned vulnerability source. The idea behind defining cases in terms of vulnerability sources is; while decision-makers are assigning ratings on vulnerability sources, they can retrieve similar past project experiences (cases) that are matched with the selected vulnerability source; that is they were also occurred due to the selected vulnerability source.

All the concepts mentioned by the experts are recorded as case descriptions as well as risk-vulnerability information, ratings and consequences of these variables are stored as case summary within the database. Within this context, in order to capture the preferences of the experts about the impact of the risk events on the cost overrun percentage, 1-5 point likert scale was facilitated. "Likert scale is widely used instrument in measuring opinions, beliefs, and attitudes" (Mydin et al, 2011). The experts were requested to indicate the degree of impact of the identified vulnerability sources on case consequence based on the Likert scale of five ordinal measures. Preferences assigned to each rating scale are as follows: Very High (5), High (4), Medium (3), Low (2), Very Low (1). The conceptual framework of lessons learned database along with the knowledge information (i.e.

knowledge description, knowledge management phase, knowledge source) is given in Table 4.5.

Table 4.5: Conceptual framework of lessons learned database

Knowledge	Related Domain	Knowledge description	Knowledge management phase	Knowledge Source
Risk event histories	Case description	Experiences and knowledge gained in previous projects	Knowledge acquisition	Meetings, knowledge transfer, self-experience
Causative factors	Vulnerability factor in case summary	Causative factors for the occurrence of the risk event histories	Knowledge codification	Meetings, knowledge transfer, self-experience, vulnerability factor checklist
Causative factor distinction	Vulnerability source in case summary	Sources of the identified causative factors	Knowledge codification	Meetings, knowledge transfer, self-experience, vulnerability source checklist
Impact for cost overrun percentage	Rating	Impact of the identified vulnerability source on cost overrun	Knowledge codification	Meetings, knowledge transfer, self-experience, 1-5 scale
Consequence of risk event history	Consequence	Consequence of vulnerability source on the occured risk event history	Knowledge codification	Meetings, knowledge transfer, self-experience, consequence type checklist
Project attributes	Project information	Cases are stored with attributes of the associated project	Knowledge storage	Decision maker, Tool
Lessons learned from past projects	Lessons learned database	Knowledge codified with the related vulnerability sources	Knowledge retrieval	Tool

4.7. An Illustrative Example of Case Study Approach

To figure out an example for the how lessons learned database is constructed and how it is facilitated in the knowledge retrieval and reuse purposes, a prototype tool is developed and tested on a real shopping mall project that has operated in Turkey. The duration of the project is 20 months and its contract value is 45.000.000 $. The illustrative case is defined by the partner firm experts as well as prototype database is constructed by using the projects previously carried out by the partner firm. To demonstrate how past project cases are acquired from experts, a part of the verbal statements of them is presented below. To be noted that, the statements directly taken from the partner firm experts' are represented in quotation mark. The key words selected from the statements are underlined and statement of experts and their reviews are given in Table 4.6. It demonstrates the findings of the reviews of statements that is, extraction of risk-vulnerability parameters that caused occurrence of the acquired past project history. To be noted that, project cases will further be codified in database in accord with these extracted parameters. All of past project cases are codified with the same methodology along with the verbal analysis of partner firm experts. The storage of the project case within the lessons learned database was illustrated in Figure 4.8.

Step 1: Knowledge Acquisition

Within the knowledge acquisition phase, statement of the construction experts is captured.

Statement of the construction expert:

"Client, contractor and subcontractors of the project were Turkish and project financer of client was German. In contract clauses, neither Turkish parties nor German party specified what type of specifications was required to use for the design and construction processes. In construction, contractor used Turkish standards and specifications in architectural and structural design, as well as subcontractors performed construction tasks based on this design. However, in a visit of auditor of project financer to the site, he claimed that, he had required using German specifications and standards from contractor, and Turkish specifications and standards could not achieve his expectations and provide his requirements. He added that, his expectations were far from what was constructed. It was stated by contractor firm expert that, auditor of project financer required contractor to use German specification after the construction process had started. Thus, contractor had to stop construction works and carry out high amount of reworks."

Step 2: Knowledge Codification

Within the knowledge codification phase, statement of construction experts is reviewed as well as relevant vulnerabilities and vulnerability source are identified. Table 4.6 shows the findings of this attempt.

Table 4.6: Review of the statement of construction expert

Case ID	Statement	Corresponding vulnerability	ID	Corresponding vulnerability source	ID
10.1	neither Turkish parties nor German party specified what type of specifications was required	Contract Specific Problems	V6	Vagueness of Contract Clauses	VS23
10.1	required using German specifications and standards	Strict Requirements	V5	Strict Project Management Requirements	VS22

Step 3: Knowledge Storage

How the acquired and codified knowledge is stored within case library is illustrated in Figure 4.8.

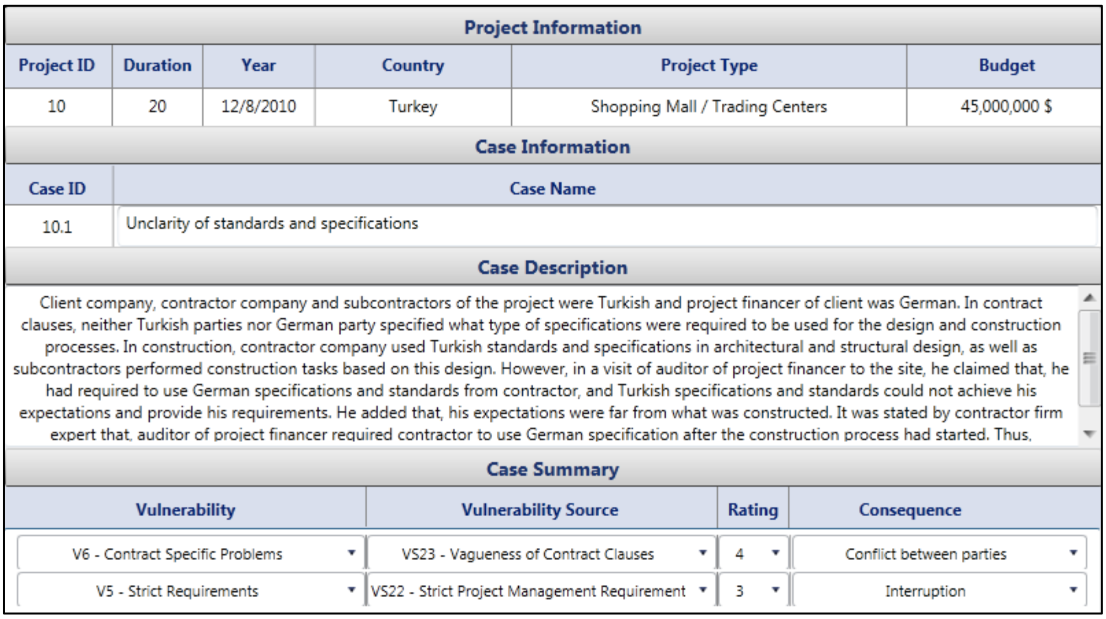

Figure 4.8: Storage of the case

Step 4: Knowledge Retrieval and Reuse

Suppose that, the decision-maker preferred to use the stored case given in Figure 4.8 when defining the magnitude of "V6- Contract Specific Problems" in one of this forthcoming project. He should firstly examine the case, risk events occurred, consequences of risk events as well as company and project characteristics that control the magnitudes of these events. As a second attempt, he should learn from the past to enlighten the probable risk event occurrences of forthcoming projects. For example, decision maker can conclude from this case that, before doing business with a foreign project party, all variations among procedures, requirements and rules regarding to the design and construction process should be defined and interpreted in the contract. In order to decide in what extent the new project can be affected by the “V6- Contract Specific Problems”, decision maker should examine requirements of each project parties of this project. Although the project financer and client are from Turkey and follow same specifications and standards with the contractor firm, they insisted on strict quality requirements that were also not specified in contract. Therefore, decision maker can conclude that his project can also be affected with the same extent of the illustrated case. In accord with this conclusion, he can define the rating of “V6- Contract Specific Problems”, as 5 (Very High).

CHAPTER 5

THE KNOWLEDGE-BASED RISK MAPPING TOOL

This chapter presents the knowledge-based risk mapping tool that is developed to enhance the course of risk management in international construction projects. This tool is designed to aid the risk assessment process by means of a risk map showing risk-related variables that may emerge when operating in international markets. The risk-vulnerability ontology reported in Fidan (2008) and the risk assessment methodology employed in Eybpoosh (2010) constitute the foundation of the tool. In the first section, the fundamentals of the tool are overviewed. In the second section, risk management phases employed in the tool is overviewed along with the presentation of the process model of the tool. Third section introduces the architecture of the tool. In the fourth section, steps that should be undertaken to use the tool, is briefly explained by demonstrating some snapshots taken from the tool. In the fifth section, other features of the tool are given. Finally, the expected benefits of the tool are discussed with referring to the research objectives claimed in the second chapter of this thesis.

5.1. Fundamentals of the Tool

The risk assessment technique employed in the study of Eybpoosh (2011) constitutes the underlying methodology of the knowledge-based risk mapping tool. Briefly, the technique utilizes SEM-based Risk-Path Model that can be used for the prediction of the following issues;

(1) Estimation of the probable magnitudes of the risk-related variables based on the known vulnerability magnitudes and pre-identified interdependency coefficients,

(2) Estimation of the probable impacts of the interrelated risk paths on the cost overrun percentage.

Although, the technique offered in the study of Eybpoosh (2011) provide construction practitioners the examination of magnitudes of risk variables that inherent in the project circumstances, its prediction process was formulated in an Excel worksheet. However, within the context of this study, it is argued that computerization of the prediction process enhances the benefits of the facilities offered by the SEM-based risk assessment technique. Based on the algorithm of the SEM-based risk assessment technique, the developed tool offers estimation of the above-mentioned issues automatically.

In addition, the developed tool is designed in a way that, it enables the storage and retrieval of the risk-related knowledge. For the utilization of risk-related knowledge in risk assessment process, lessons learned database is incorporated in which risk event histories of past project will be stored. The developed database can also be used for the development of an organizational risk memory as well as can be utilized within the purpose of learning from risk event occurrences of previous projects.

Tool can be facilitated in four different stages of a project; (1) bid evaluation and preparation, (2) contracting, (3) construction, (4) post project commission and evaluation. It is believed that, construction practitioners can facilitate the tool in the earlier stages of a project such as feasibility studies, bidding decisions, bid preparations, risk identification, cost estimations, or contracting. In addition, when constructing or operating a project, tool can be facilitated to assess in what extent an adverse change in project circumstances, environmental conditions, or performances of project practitioners can be resulted in cost overrun, as well as to examine probable risk path scenarios that can be occurred due to an occurred adverse change. Moreover, tool allows the evaluation of risk occurrence of the recently finished projects as well as the examination of critical risk path scenarios emerged in these projects. Apart from capturing the risk severities, in post project commission and evaluation, construction practitioners can capture the risk-related knowledge that they have been gained throughout the lifecycle of a recently finished projects. Participation of all team members of a project in post project commission and evaluation phase will be an encouraging effort to develop company level lessons learned database.

5.2. Risk Management Process Employed in the Tool

Within the existing literature, authors widely accepted risk management as a systematic process composed of four primary steps; risk identification, risk assessment, risk response and risk monitoring. The proposed tool employs a risk management workflow composed of five major phase; risk identification, risk assessment, risk evaluation, risk handling and monitor, and risk review and documentation. Function modeling method (IDEF0) is used to develop process model of risk management workflow that is risk management activities carried out during the tool use. The process model of the tool is given in Figure 5.1. The first phase of the risk management process is the identification of risk-related variables that inherent in international construction projects. The risk map structure allows the identification and classification of risk-related variables to systemize the process. Thus, it is not required from construction practitioners to identify and classify risk-related variables, by themselves. Risk map structure consists of vulnerabilities, risk sources, risk events, and risk consequence; however, vulnerability sources of the given vulnerabilities, as well as attributes of the defined vulnerability sources are also involved in the process. However, vulnerability sources can be examined in assessment process, and their given attributes can be identified only if they are used in quantifying vulnerability sources. The classes of risk-related variables based on their hierarchical order in a project, are given in Figure 5.2. At the root of the hierarchy, attributes of vulnerability sources are located. Attributes represent the events whose existence or occurrence may influence the occurrence of the relevant vulnerability sources. Same logic is valid between the vulnerability sources and vulnerabilities. However, attributes of a given vulnerability source is more specific, they represent the inner characteristics of vulnerability source. The relationship between vulnerability source and vulnerability is more diverse. For example, attributes of vulnerability source 'Instability of Economic Growth' are related with the economic variables of a country, and limited in representing economic growth of a country. However, vulnerability source 'Instability of Economic Growth' is belong to vulnerability 'Adverse Country Related Conditions' which also includes sources related with political, legal or social conditions of country.

The second and third phases are qualitative and quantitative risk assessment phase that allow the quantification of the probable magnitudes of the risk-related variables as well as estimation of the impact of the each risk path on the risk consequence. Within this process, the severities of vulnerability sources should be defined by decision makers for which they can take the assistance of vulnerability source attributes or risk event histories retrieved from lessons learned database that contain risk occurrence knowledge of past projects. Based on the known vulnerability source magnitudes, tool will carry out risk assessment by the coefficients found by SEM and estimate the probable magnitudes of the vulnerabilities, risk sources, risk events, risk consequences as well as impacts of risk paths on risk consequence.

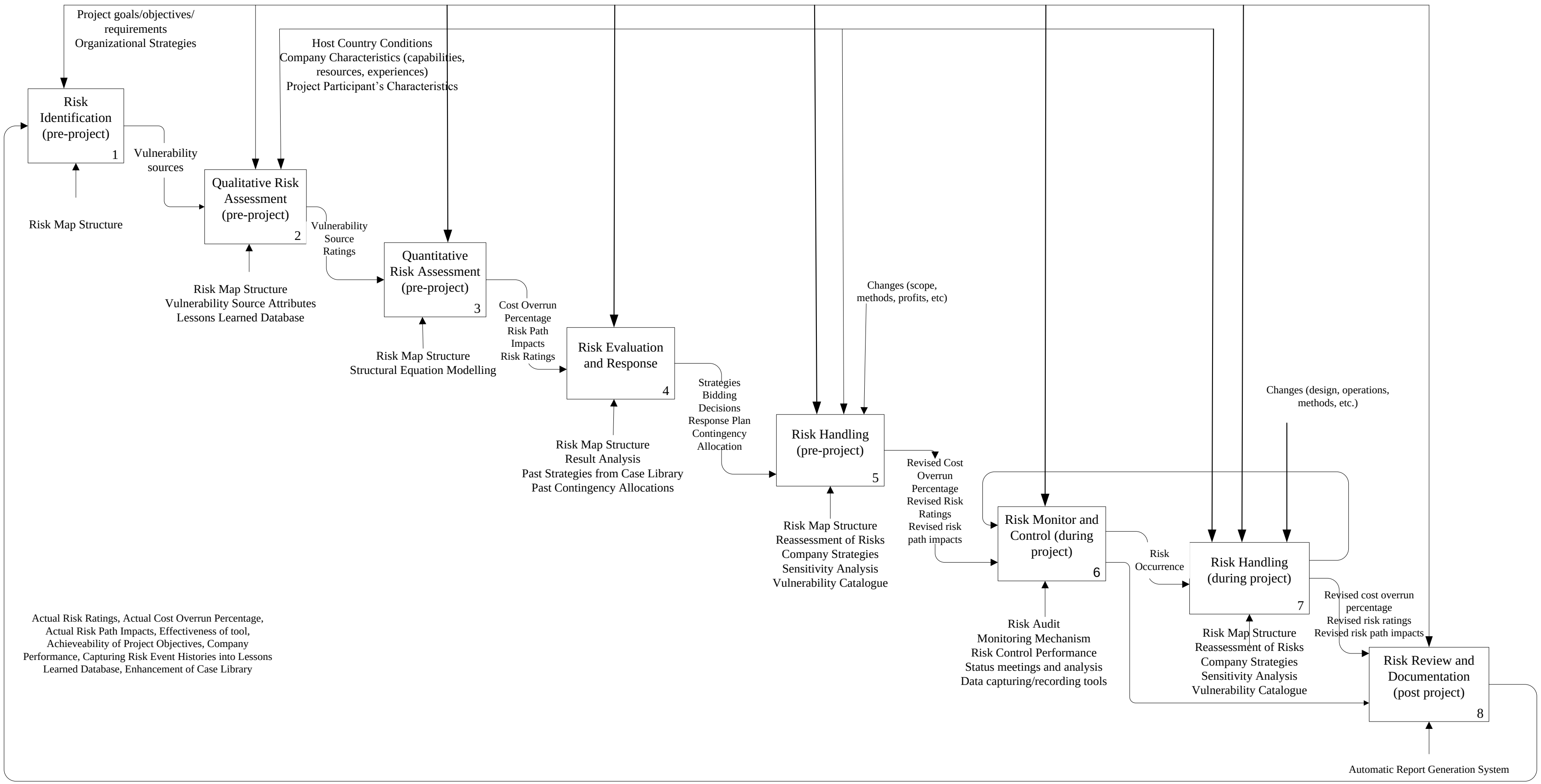

Figure 5.1: Process model of the risk mapping tool

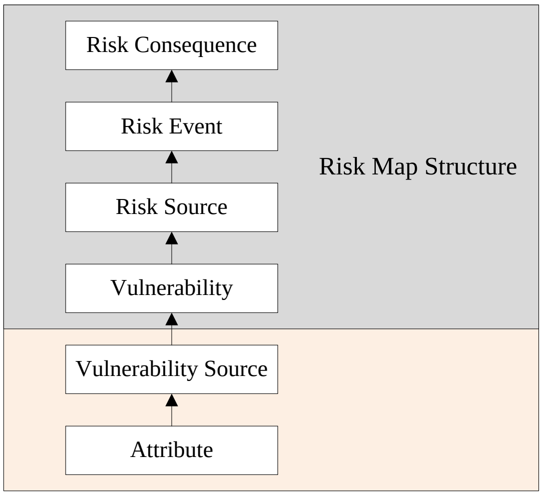

Figure 5.2: Risk identification components

Risk evaluation is the fourth phase that allows the examination of the findings of the risk assessment phase; estimated risk magnitudes and risk path impacts. Through the evaluation of the risk assessment outcomes, decision makers may prepare response strategies and action plans to be facilitated throughout project lifecycle, may decide on bidding decisions, may revise feasibility studies, and may incorporate additional contract clauses to cope with probable unfavorable changes in project conditions. Risk handing carried out in the pre-project stage is the fifth phase, by which decision makers can implement some mitigation strategies or improve company characteristics to avoid probable vulnerabilities and risk variables. Decision makers can utilize sensitivity analysis in this phase or reassess the impact of risk variables with the improved vulnerabilities. Risk monitoring and control, and risk handling during project are the sixth and seventh phase of the process as well as are repetitive phases in the case of occurrence of risks. Final phase is the risk review and documentation conducted in the post-project stage. Within this phase, risk assessment results can be reported and shared among organization with the use of automatic report generation system. The reports taken from the system give the actual risk assesment results (i.e. actual cost overrun percentage) as well as enable to understand achievability of project objectives, company performance, and effectiveness of the tool. In addition, in the case of risk events and lessons learned are captured during the project lifecycle, another major output of the risk assessment would be the enhancement of the organizational lessons learned database.

5.3. Architecture of the Tool

The tool has been developed using Microsoft Visual C Sharp and operates under all versions of Microsoft Windows. The first interface of the risk mapping tool is the start-up screen where the list of projects that have been assigned into the tool, can be examined. The start-up screen directs the users to two main functions as; opening a previous project and creating a new project. The second interface, main window, is the user interface that controls the features of the tool as well as allows an access between user and the tool. User interface directs the users to seven distinct tool functions; operations about projects, operations about cases, assessment process through risk map, generation of results, sensitivity analysis, generation of reports and help about the tool functions. The access between users and these functions is enabled by implementing separate tabs for each function within the user interface toolbar. These tabs are; project, case, risk map, results, sensitivity analysis, reports, help. Some shortcuts were also put at the bottom of the toolbar for the convenience of the user. These shortcuts enable the users to access to the home page, to add new case, to access case library, to define attribute settings, to access risk map and help.

All functions under the user interface operate under different interfaces. Project tab facilitates four different operations; open project, add new project, edit project and remove project. Although all these interfaces, except add new project, have similar interfaces (project list interface), their functions are abled in different button options. The users can open, edit, or remove projects from the list of projects that will be retrieved in the project list interface. Open or remove project operations are not linked with any other interface, however edit or add new project operations are linked with project information interface. For editing a project, the users should make necessary adjustments or changes and save the project on the retrieved information of the selected project from the project list. Similar operations and operation interfaces with project tab is valid for case tab. How a project and a case can be add to the tool, will be explained in the further sections of this study.

The case library tab operates under a single interface that shows the list of projects and their cases that have been assigned into the tool previously. The risk map tab operates under a single interface, however it will further be interlinked with attribute analysis, and lesson learned database interfaces in the risk assessment process. The results tab gives access to the three different interfaces allowing the examination of the risk assessment results. These interfaces are; risk rating results, risk path results and cost overrun results. The sensitivity analysis tab is followed by a single interface where quantification of cost overrun percentage with respect the changes in the vulnerability sources, is carried out. Risk assessment outcomes given in the results tab, can be documented from the reports tab. A part from the risk assessment results, this tab also facilitates case report and sensitivity analysis report. Case report documents the risk event histories that are retrieved in the assessment process from the lessons learned database, and sensitivity analysis report documents the findings of the pre-performed sensitivity analysis. This tab also covers report settings interface where company or user-related information can be fed into tool in order to assign them on the documented reports. The final tab, help tab, provides a user tutorial in which functions of the tool is explained with the snapshots taken from the tool.

In total 49 interfaces are facilitated within the attribute analysis purposes. The function of the lesson learned database operates under a single interface. With including 49 attribute analysis interfaces, tool operates 68 interfaces in total. To be noted that, due to space limitations; an illustrative interface of attribute analysis window is given in this study. Noticeably, all other interfaces of attribute analysis operate under the same framework; however, they retrieve different attributes information.

5.4. Application of the Tool

The proposed risk mapping tool can be used for two major purposes; development of lessons learned database to establish organizational risk memory, carrying out risk assessment process through the proposed risk map to quantify cost overrun percentage of international projects. To be noted that, the structured database can also be incorporated in risk assessment process by retrieving risk-related knowledge of previous projects. In addition, decision makers can benefit from the other features of the tool such as automatic report generation system or sensitivity analysis. Other features of the tool will be explained in the following section.

Independent from which purpose(s) the tool will be applied (i.e. development of database or assessment of risks), the initial step in the tool application is the entry of project information. Thus, firstly entry of project information into the tool is introduced and then, the steps required to develop lessons learned database as well as assess risk-related variables, is explained.

5.4.1. Entry of Project Information

Pre-defined project information entry form aids the users to identify what information is needed to assign the project into the tool. The 'Project Information' interface is given in Figure 5.3 along with an illustrative project information data. The fields of project information interface are as follows;

Project ID: Project ID will be defined automatically based on the number of projects that has been defined in the tool previously.

Project Name: Project name should be defined as was in the contract.

Country Name: Country name should be selected from the complete list of countries in the world.

Project Type: Project type should be selected from the complete list of common project types. In this study, these types are assumed as residential building, shopping mall/trading centers, health centers (hospitals, clinics), schools/universities/culture centers, hotels, museum, sports facilities/stadiums, infrastructure, industrial buildings/power plants, highways/rail systems/fast trains, water and sewage treatment plants, dams and others.

Project Description: A brief description and scope of the project should be given.

Start Date: Start date should be selected from the agenda.

Duration: Contractual duration should be specified in months.

Finish Date: Finish date of the project would be automatically estimated by the tool based on the start date and project duration.

Contract Value: Contract value is the value that is initially specified in project contract.

Currency: Currency of the contract value should be selected from the currency list. In this study, three currencies are defined in the tool; USD- US Dollars, EUR- Euro, TRY- Turkish Lira.

Project Size: Project size is essential to classify projects in accord with their contractual value. In this study, project size intervals are in USD and they are classified as; small (0-10 million USD), medium (10-30 million USD), and large (greater than 30 million USD). Tool will automatically identify the project size based on the contract value. In the case of contract, value is in EUR or TRY, it can be converted in USD with the currency converter that was installed into the tool. As long as the tool is used from any computer with internet access, currency exchange rate values will be retrieved from internet and converted into USD.

Contract Type: Contract type is the pre-defined project delivery type and it should be selected from the contract type list. In this study, six project delivery type are utilized; design-bid-build (DBB), design-build (DB), build operate transfer (BOT), separate contracts, self-performance (force account), construction management (CM).

Payment Type: Payment type is the progress payment type specified in the contract. Four different payment types are defined in the tool; lump sum (LS), unit price (UP), cost plus fee (CF), and mix type.

Company's Role in the Project: The role of the company in the project should be selected from the list that defines probable role of companies as; owner, contractor, subcontractor, JV partner, consortium partner, consultant and other.

Owner/Client/Partner Name: Information such as 'contractor name', 'client name' or 'the partnership name' will also be asked to the decision maker in accord with the data of 'company's role in the project'. For instance, in the case of 'company's role in the project' is defined as owner, then the tool will automatically ask 'contractor name'.

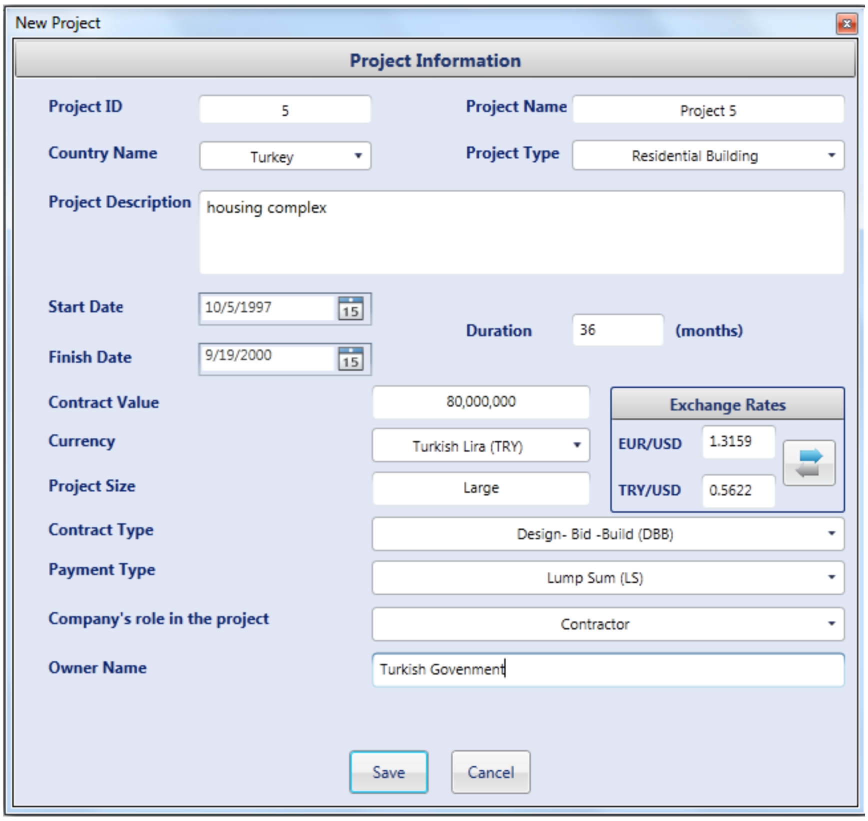

Figure 5.3: Snapshot taken from the 'Project Information' interface

5.4.2. Development of the Lessons Learned Database

To create individual or organizational lessons learned database, decision makers should create their own past project histories by acquiring their knowledge and experience into the lessons learned database. As was discussed in chapter 4, the incorporation of experiences and knowledge of several decision-makers enhances the expected benefits of facilitating the database. Thus, it is recommended that all team members of a project or within an organization should collaborate in the process of creation of the database. Within this process, decision-makers should create each past project separately and define project information with the method introduced in the previous section. After assigning the project into the tool, they should create risk event histories that were occurred in their assigned project. To be noted that, this process repetitively continues until decision makers feel comfortable about the competency level of the database. Figure 5.4 illustrates the snapshot taken from the 'Add New Case' interface along with the sample project case. As can be seen from Figure 5.4, the assigned project information will be retrieved and displayed in 'Project Information' heading of the interface. The steps that should be carried out to construct organizational lessons learned database are;

(1) **Assigning case information by defining case name and case ID.** Defining case name aids decision makers to follow cases listed on the "Case Library" in a more easy way. In addition, case ID identification system is developed that shows the sequence of cases of a given project. The first number of case ID represents project ID and the second number indicates the case code of the related project. Case IDs' will be automatically displayed at the 'add new case' interface in each case adding process.

(2) **Explaining project risk event histories as case descriptions.** This step is the knowledge acquisition phase of the technique employed to develop lessons learned database. How the decision makers should explain the risk event histories have been explained in the previous chapter of this study.

(3) **Codifying the case into the case summary.** Structuring the case summary is the knowledge codification phase of the technique employed in the development of the lessons learned database process. When codifying the case, decision maker should select vulnerability, vulnerability source of the case, define the consequence the vulnerability source, and assign the impact (rating) of the vulnerability source on the selected consequence. Information within the 'case summary' will be assigned with the use of four different dropdown menu that are structured within the interface. Vulnerabilities will be selected from the list of factors that are shown in the dropdown menu. After selecting the vulnerabilities, sources of the selected vulnerabilities will automatically be retrieved by the tool. In the case of multiple vulnerability factors were occurred in a risk event history, additional row(s) should be created by clicking on the 'add' button to create another case summary row.

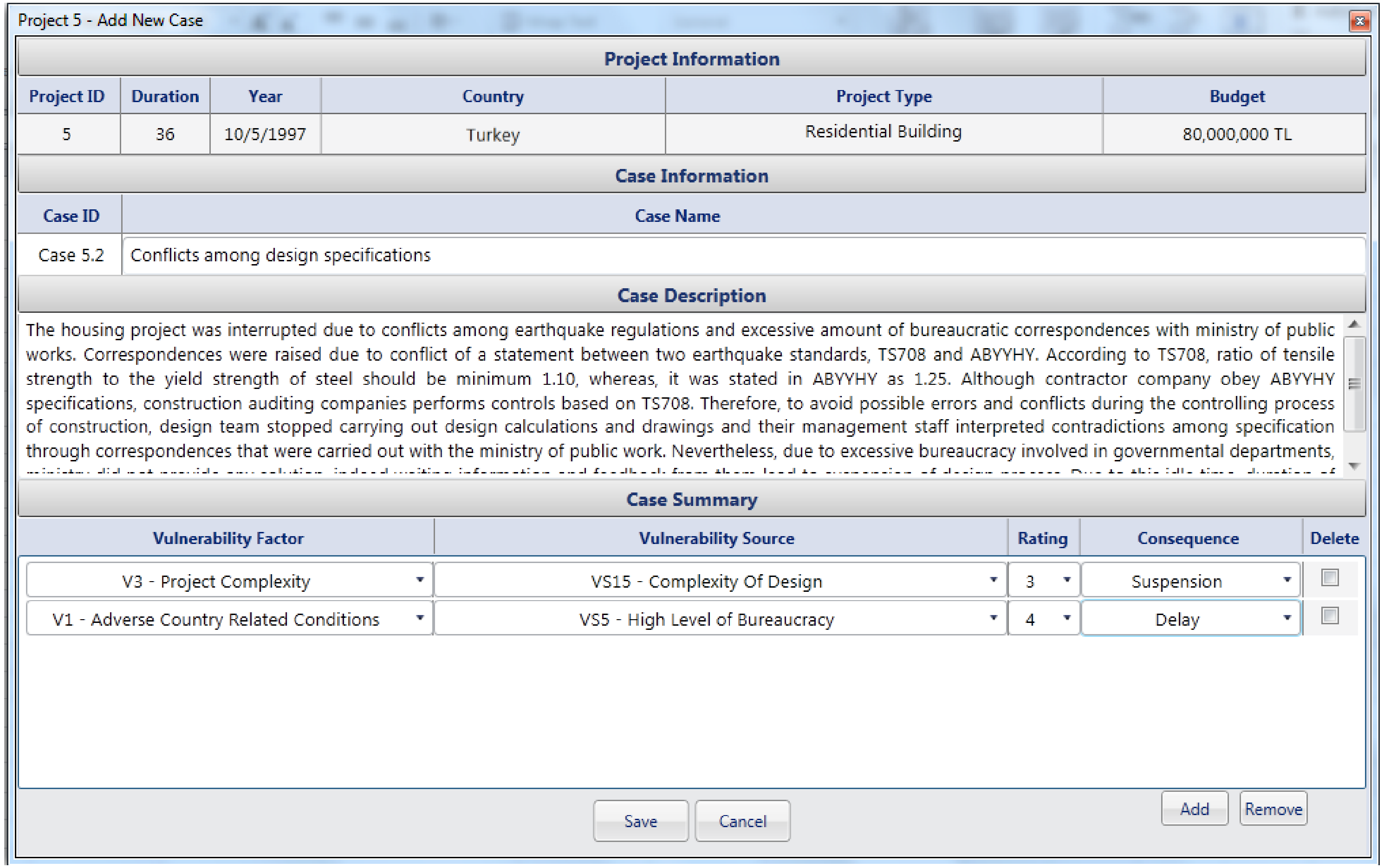

Figure 5.4: Snapshot taken from the 'Add New Case' interface

5.4.3. Knowledge-Based Risk Assessment Process

Basically, the risk mapping tool comprised of following tasks for the development of lessons learned database; (1) entry of the past project information, (2) entry of past project cases. In addition, steps that should be performed during the risk assessment are; (1) entry of a new project, (2) opening risk map interface, (3) defining input values, (4) evaluation of results.

With the assigned ratings to the vulnerability sources, the tool automatically quantifies the magnitudes of the risk-related variables (i.e. vulnerabilities, risk sources) that are located on the risk map. In addition, the impact of each risk path on cost overrun percentage as well as the sequence of these paths in the order of highest contribution to the lowest on cost overrun percentage will be estimated by SEM. After all the necessary information such as ratings of vulnerability sources are fed into the model, decision-makers will not carry out the risk assessment calculations by themselves (manually) and assessment procedure will be considerably easy.

Figure 5.5 demonstrates the 'Risk Map' interface of the risk mapping tool. Blue colored boxes represent vulnerabilities and they are linked with 'Vulnerability Source Assessment' interface. The magnitudes of the vulnerabilities will be automatically quantified by the tool after the magnitudes of the vulnerability sources of the related vulnerabilities are assigned by decision-makers. The determination of the magnitudes of the vulnerability sources will further be introduced. In addition, green colored boxes represents risk sources and risk events, and red colored box is the risk consequence (cost overrun). To be highlighted that, the magnitudes of the risk sources, risk events and risk consequence will be automatically estimated through SEM with the pre-estimated magnitudes of vulnerabilities. Unlike the vulnerability boxes, the boxes representing the risk sources, risk events and risk consequence are not interlinked with any other interface.

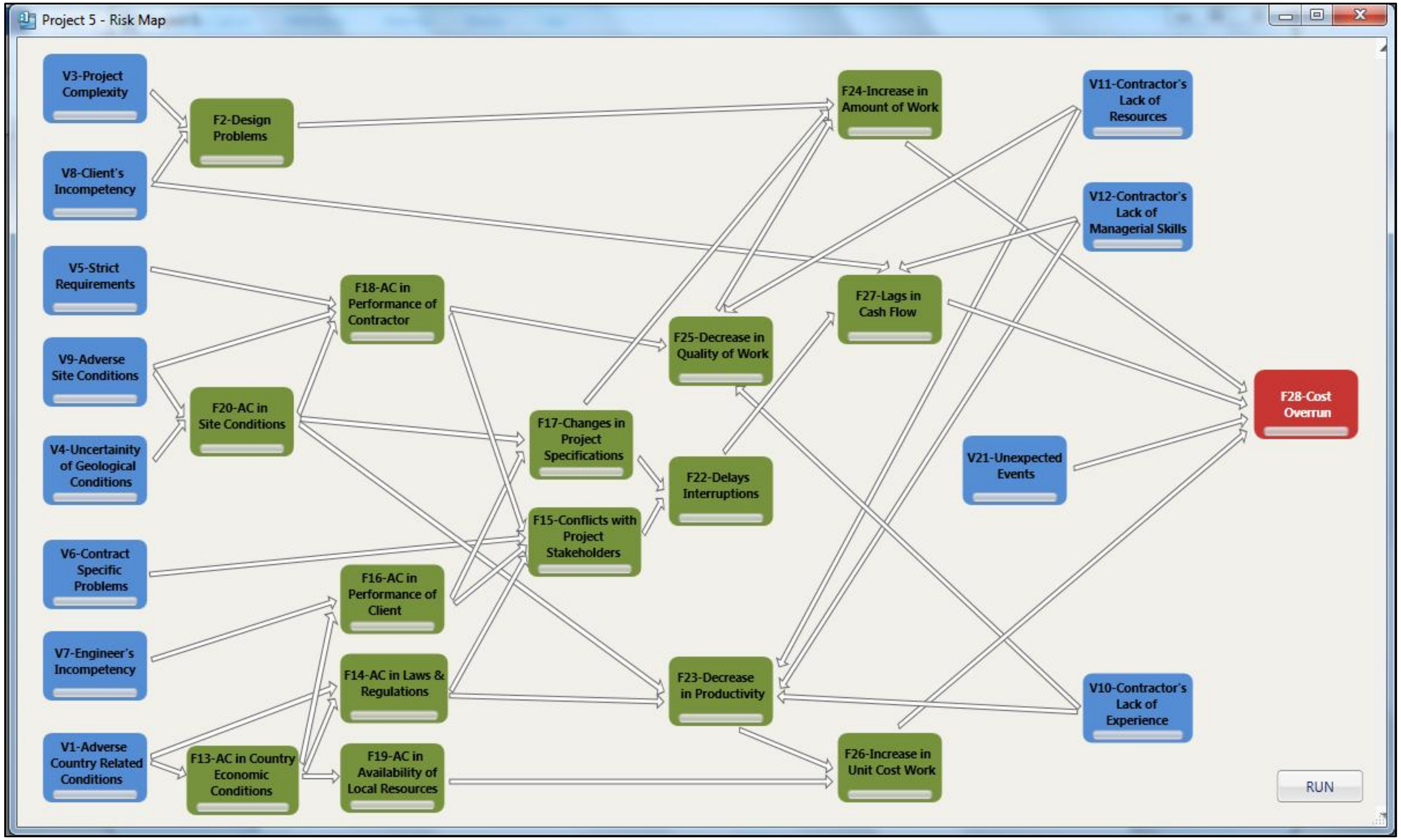

Figure 5.5: Snapshot taken from the 'Risk Map' interface

Risk assessment process of the tool starts with the selection of the vulnerabilities (blue boxes). After selecting vulnerability, sources of the selected vulnerability will be listed. An illustrative snapshot is given in Figure 5.6 to demonstrate how the vulnerability sources of the selected vulnerability are retrieved and listed. The snapshot given in Figure 5.6 represents the 'Vulnerability Source Assessment' interface of the vulnerability 'Adverse Country Related Conditions'. It was expected from decision makers to assign rating of the vulnerability sources of each vulnerability variable. Vulnerability source ratings can be assigned by three ways; facilitating attribute analysis, retrieving similar cases that are matched with the related vulnerability source or by the decision makers themselves without any aid. 'AR' button opens 'Attribute Analysis' interface, and 'LL' button opens the interface of 'Lessons Learned Database'. The operation mechanism of vulnerability source analysis is given Figure 5.7. In the case of decision makers aim to define ratings without any aid, they will directly enter the rating in the box under the 'rating' heading.

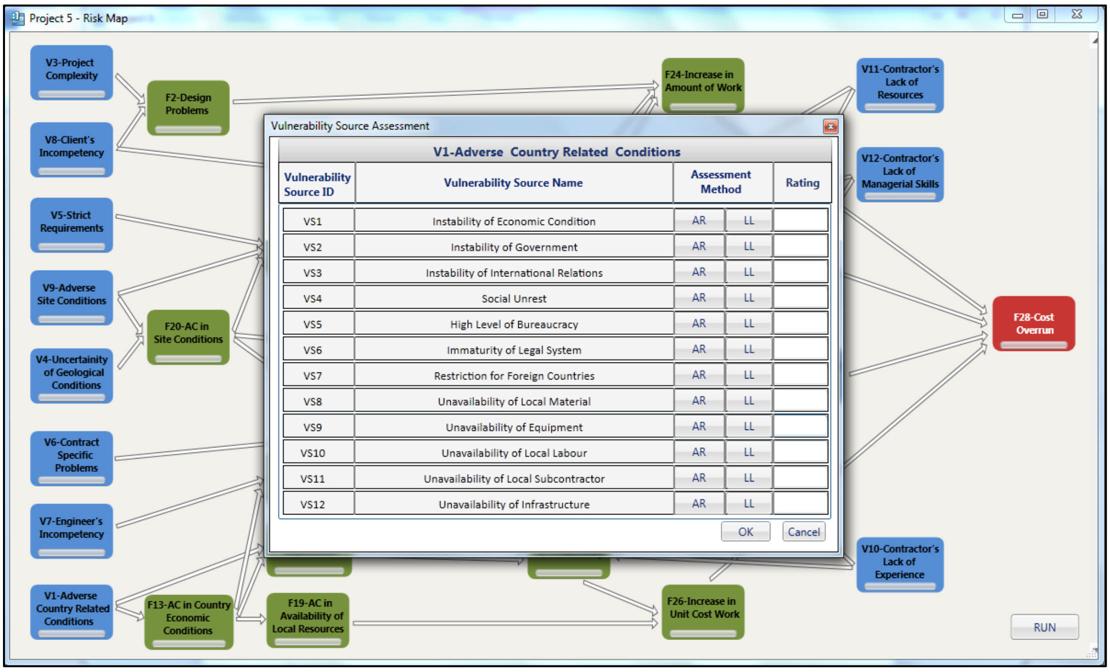

Figure 5.6: Snapshot taken from the 'Vulnerability Source Assessment' interface

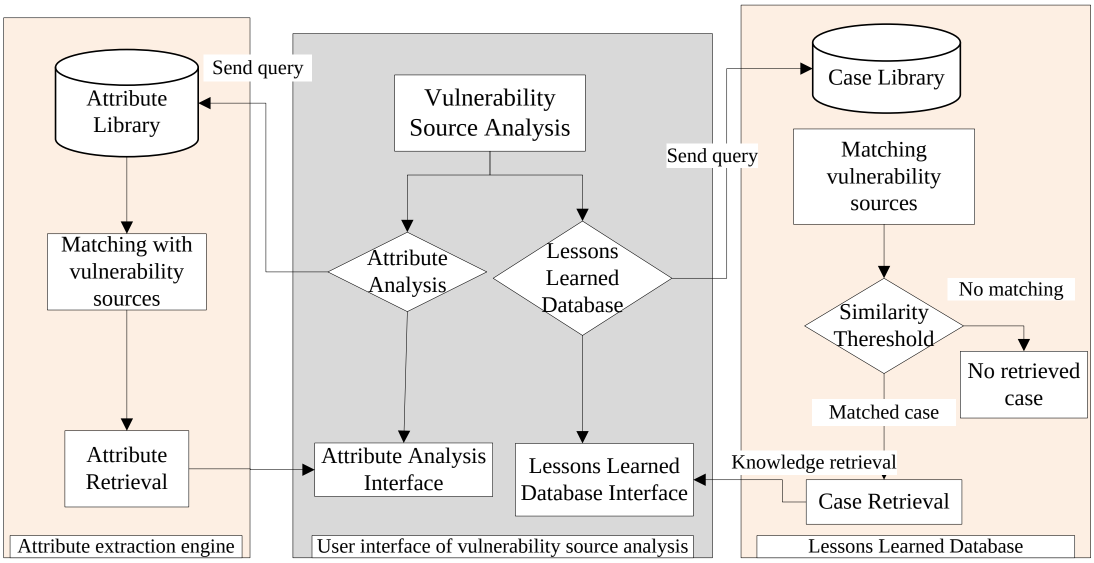

Figure 5.7: Operation mechanism of vulnerability source analysis

5.4.3.1. Use of Attributes

The objective of structuring the vulnerability source attributes has been introduced in Chapter 3. In this chapter, how the attributes could be used in the risk assessment process, is explained.

Decision maker can facilitate attribute analysis with the use of 'AR' button as shown in Figure 5.6. Figure 5.8 represents the snapshot taken from the 'Attribute Analysis' interface. Within this interface, 'Project ID' and 'Project Name' will be automatically retrieved based on the predefined project information. Similarly, the relevant vulnerability and vulnerability sources will be automatically retrieved and designated on the 'Vulnerability ID', 'Vulnerability', 'V.Source ID' and 'V.Source Name' boxes. The interface itself represents the relevant attribute names and descriptions. To utilize attributes in quantifying the magnitudes of vulnerability sources, decision makers should define attribute weights and ratings. Attribute weights represent the level of importance of the given attribute within the all retrieved attribute list. Attribute ratings are the level of impact of the given attribute on the vulnerability source rating. Attribute weights can be identified in three ways; assigning equal weights to each attribute, assigning default weights, or assigning new weights in every single project. 'Use equal weights' box facilitates distributing equal weights among attributes by dividing amount of attributes to one. Another option is, assigning default weights by clicking on the 'Use Default Weights' button. In addition, different attribute weights for each new project can be set by tool user, especially when specific project conditions are emerged or characteristics are existed. For instance, different circumstances inherited in project environment or variations occurred in organizational characteristics/competencies might lead decision makers to assign specific attribute weights. In this case, rather than using default weights, assigning project-based weights in accord with the level of importance of the given attribute within the project or organization environment will be a more realistic and accurate approach. In addition, attribute ratings from 1-5 scale should be identified based on the question of how the given attribute can influence the occurrence of the related vulnerability source. With the defined attribute weights and ratings, tool will automatically calculate the magnitudes of the vulnerability sources ratings. The calculation formula for the vulnerability source severity is as follows;

Magnitude of vulnerability source =
$$\sum_{i=1}^{n} Ratings\ of\ attributes * weight\ of\ attributes$$

The rating of the vulnerability source will be quantified and given in ‘Vulnerability Source Rating’ box located on the ‘Attribute Analysis’ interface. In addition, vulnerability source ratings estimated through the use of attributes, will automatically be displayed in the related box located on the ‘Vulnerabilty Source Assessment’ interface. However, decision makers can edit or totally delete this value.

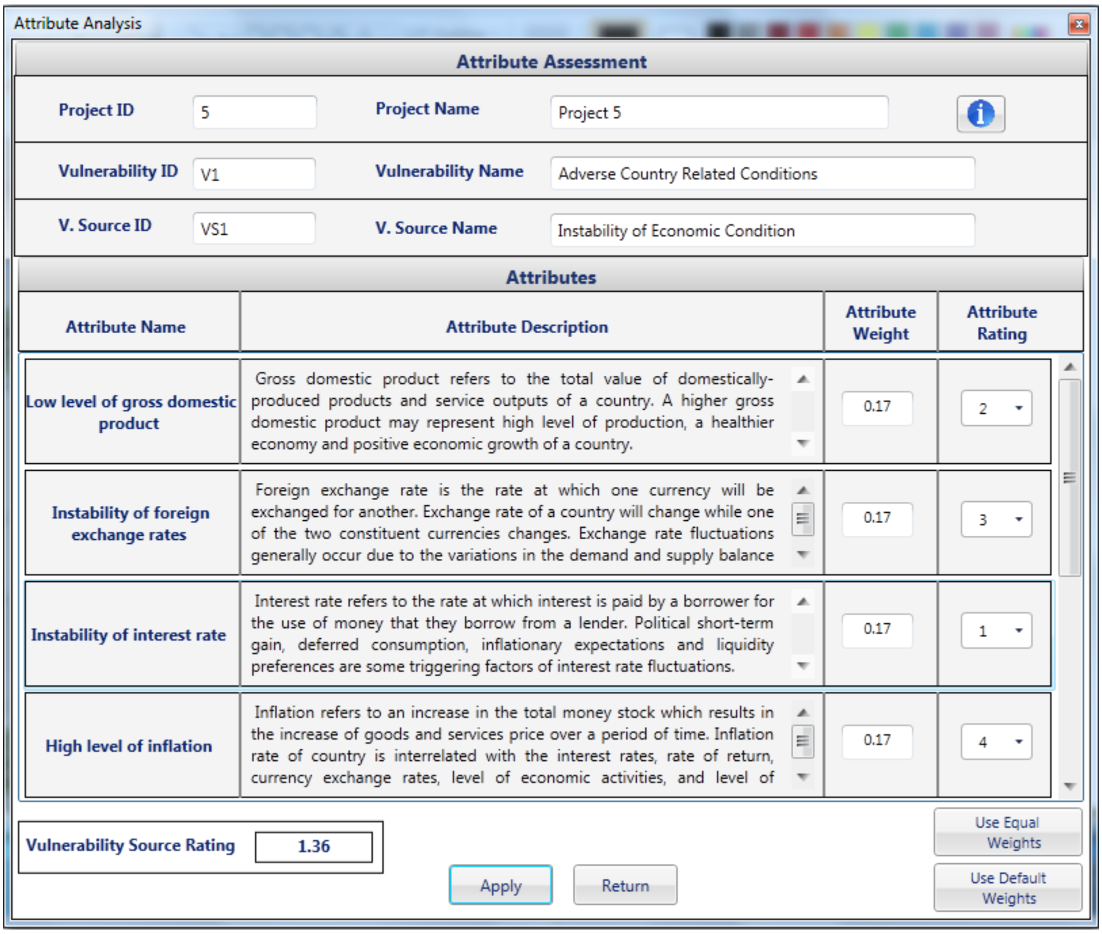

Figure 5.8: Snapshot taken from 'Attribute Analysis' interface

5.4.3.1.1. Identification of Attribute Weights

To use default weights for attributes, decision makers should firstly define default weights through the 'Attribute Settings' interface. Figure 5.9 gives the snapshot taken from the 'Attribute Weight Settings' interface. The default weights, unless be edited, can be applied in attribute analysis of every single project. To assign default weights, decision makers should select a vulnerability, select one of its sources, and assign default weights to the retrieved attributes. This process should be carried out repetitively until all attributes of all vulnerability sources will be finished. The sum of the attribute weights of a vulnerability source should be equal to one. However, in case the sum of weights is more or less than one, the tool displays a warning message and asks whether to normalize these values. Normalizing the values refers to the automatically re-estimation of the pre-estimated weights with equalizing the sum of weights to one and maintaining relative ratios of attribute weights. If attribute weights are not normalized, it is required to re-assign weights with equalizing the sum of weights to one.

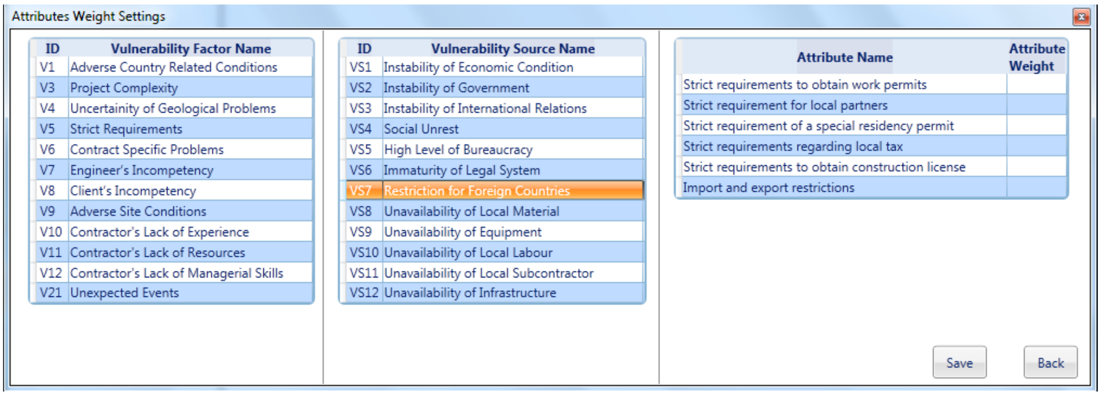

Figure 5.9: Snapshot taken from 'Attribute Weight Settings' interface

5.4.3.2. Use of Lessons Learned Database

Apart from using attribute analysis, decision makers can also take the assistance of the lessons learned database when assigning ratings of vulnerability source. As it was mentioned previously, past project cases were classified with respect to their causative vulnerability and related sources of these vulnerabilities. Figure 5.10 demonstrates the snapshot taken from the 'Lessons Learned Database' interface with examplifying how similar past project cases will be retrieved from the database. To be noted that, using lessons learned database constitues the knowledge retrieval and reuse phases of the knowledge management process employed in the tool. The 'Lessons Learned Database' interface can be opened by clicking on the 'LL'button located on the 'Vulnerability Source Assessment' interface. The database will automatically retrieve the project cases that are codified in the database previously with the relevant vulnerability soruces. By clicking on the case description box of each case, the project information of the case and case summary (vulnerability source, rating and consequence) will be demonstrated at the toolbar located on the right side of the interface. Retrieved cases can be downloaded in PDF by clicking on the 'Download PDF' button as well as printed by 'Print' button. Retrieved cases initially sorted with respect to their case ID, however they can also be sorted based on their project attributes (i.e.project year, duration). In addition, retrieved project cases can be refined with respect to their project attributes with the use of 'Refine Results' button. Moreover, keywords can be searched from the retrieved cases. Tool will automatically underline the words that are matched with the word entered in the 'search within results' box. As was examplified in Figure 5.10, 'construction' is entered as a keyword and word 'construction' in case descriptions is highlighted by the tool.

5.4.4. Risk Assessment Outcomes

There are extremely high amount of vulnerability sources that are facilitated in the risk assessment process. During risk assessment process, decision makers have to rate various vulnerability sources. It is argued that, it may be confusing to examine which vulnerability sources are not assessed yet. Thus, it is decided to label vulnerabilities in yellow to indicate that its' vulnerabilty sources are assessed. After all sources are assessed, risk assessment process will start by clicking on the 'run' button. Ratings of the vulnerabilities, risk sources, risk events, risk consequences, as well as impacts of each risk path on the cost overrun percentage will be estimated by SEM. An illustrative risk assessment result is given in Figure 5.11. To be noted that, the color of the each box as well as bar diagrams located into the boxes will vary with respect to the magnitude of the related variables. As the variables have high ratings, the length of the red lines in bar diagrams will be longer as well as the color of the boxes will be darker. Figure 5.11 also demonstrates 'Cost Overrun Result' interface that is automatically displayed after run operation of the tool is completed. 'Cost Overrun Result' interface include cost overrun percentage, the five most critical risk paths that have highest contribution to cost overrun percentage, and impact of these paths on cost overrun.

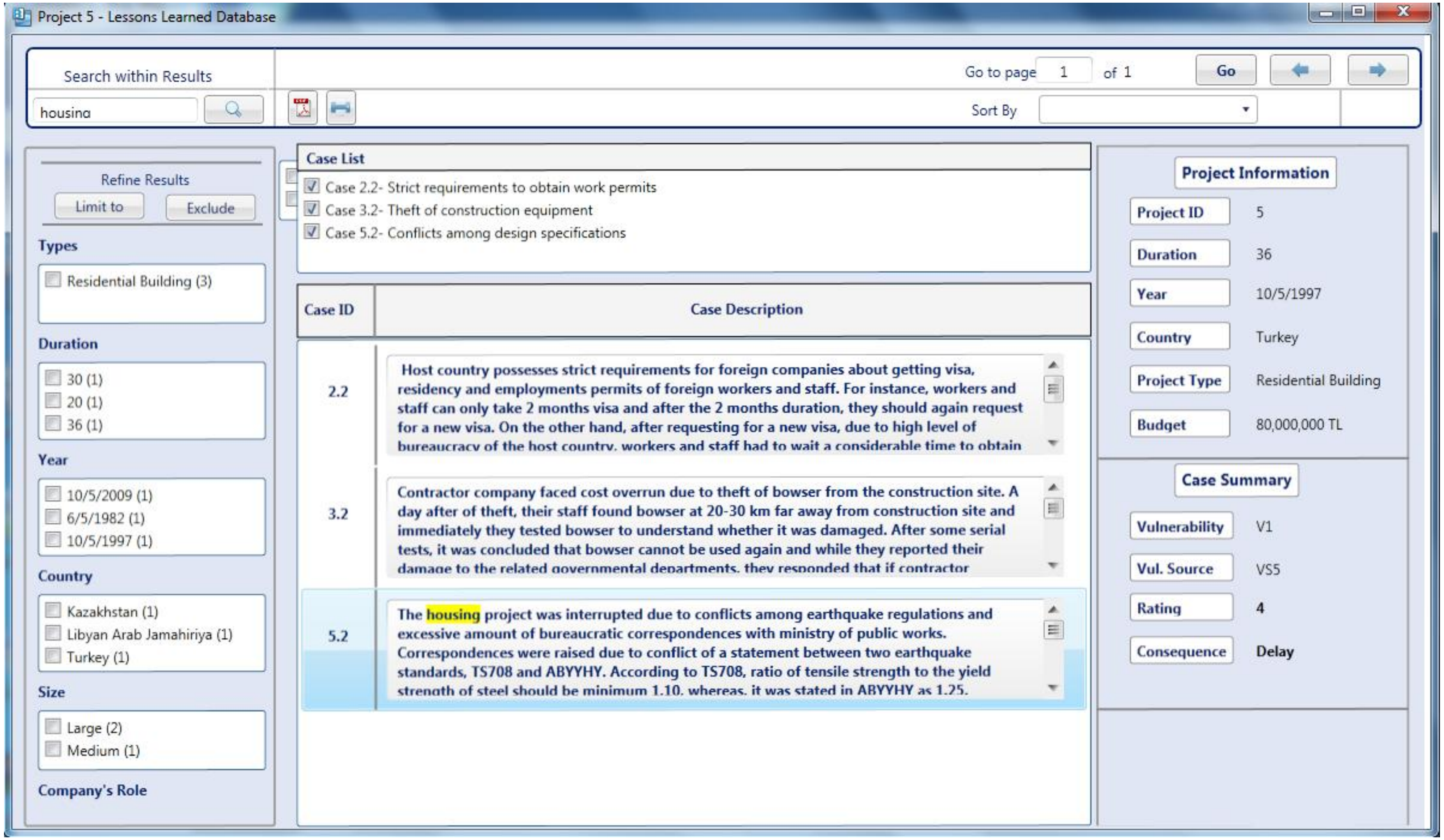

Figure 5.10: Snapshot taken from the 'Lessons Learned Database' interface

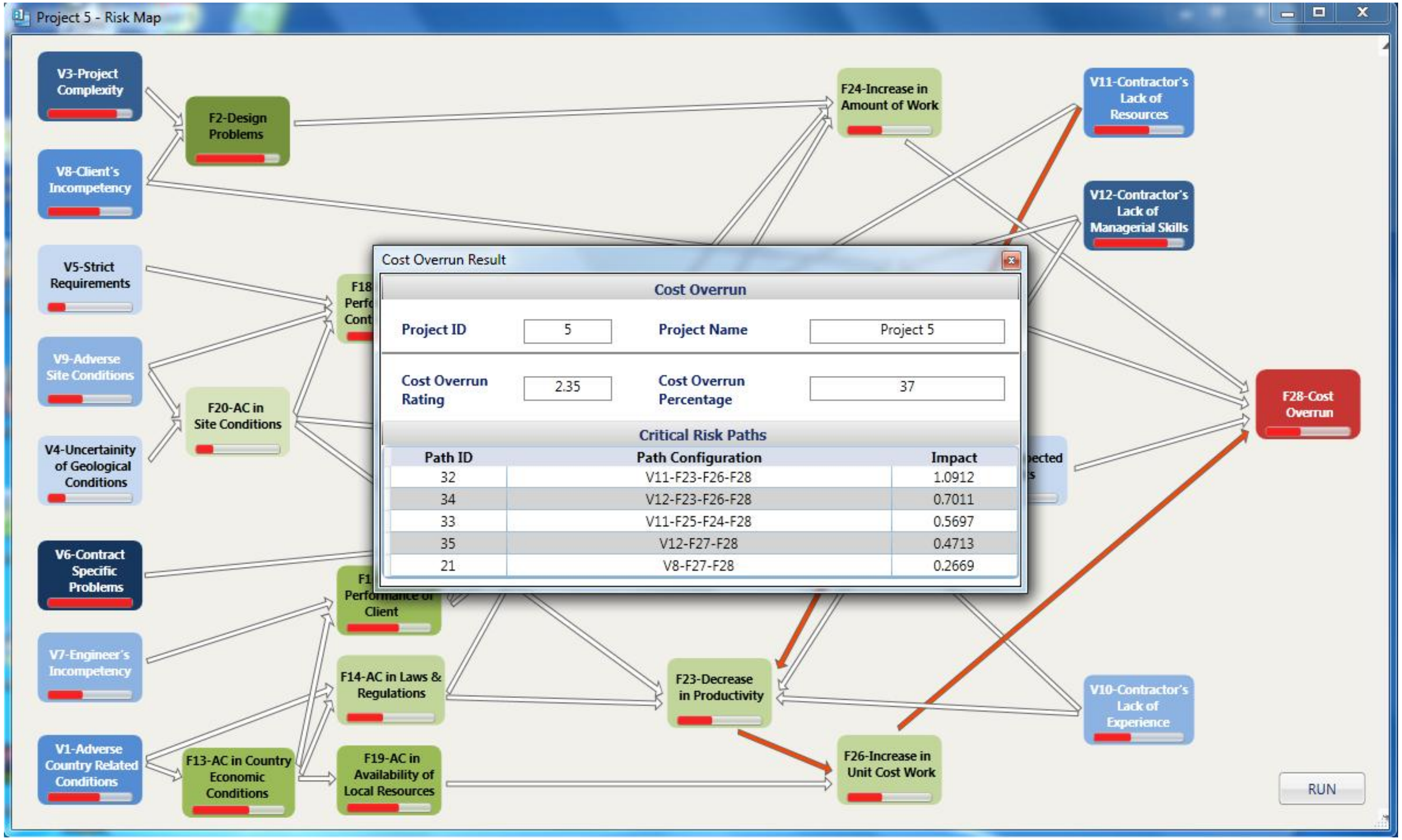

Figure 5.11: Snapshot demonstrating risk assessment results

5.4.5. Evaluation of Risk Assessment Results

There are three type of results obtained through the risk assessment process; risk ratings result, risk path result, and cost overrun result. Risk rating results show ratings (magnitudes) of the risk-related variables in 1 to 5 scale as well as types of these variables. Risk path results give a overall list of risk paths and their impacts on the cost overrun percentage. The paths are sorted as highest impact to the lowest. Cost overrun result represents the cost overrun percentage, the five most critical risk paths that have highest contribution to cost overrun percentage, and impact of these paths on cost overrun.

5.5. Other Features of the Tool

The risk mapping tool includes other features that are not required to facilitate when quantifying risk-related variables. However, these features assist decision makers to enhance the risk assessment process (i.e. sensitivity analysis), the evaluation of the assessment results (i.e. automatic report generation), the visualization/examination of their organizational risk memory (i.e. case library) or solely beneficial in using the tool (i.e. help menu).

5.5.1. Sensitivity Analysis

Sensitivity analysis provides the evaluation of how the change in the ratings of the given vulnerabilities will be resulted in cost overrun percentage. It gives the understanding of relationships among the magnitudes of vulnerability sources and cost overrun percentage of the project. The snapshot taken from the ‘Sensitivity Analysis’ interface, is given in Figure 5.12. As the input variables of the risk assessment process are solely vulnerabilities, only vulnerabilities are listed in this interface. Several vulnerabilities can be facilitated during the sensitivity analysis at the same time, however tool runs the ‘sensitivity analysis’ for each vulnerability factor separately. That is, the combined effect of the selected vulnerabilities on the cost overrun percentage is not considered at the same time. Sensitivity analysis results can be examined as a line chart or a bar chart.

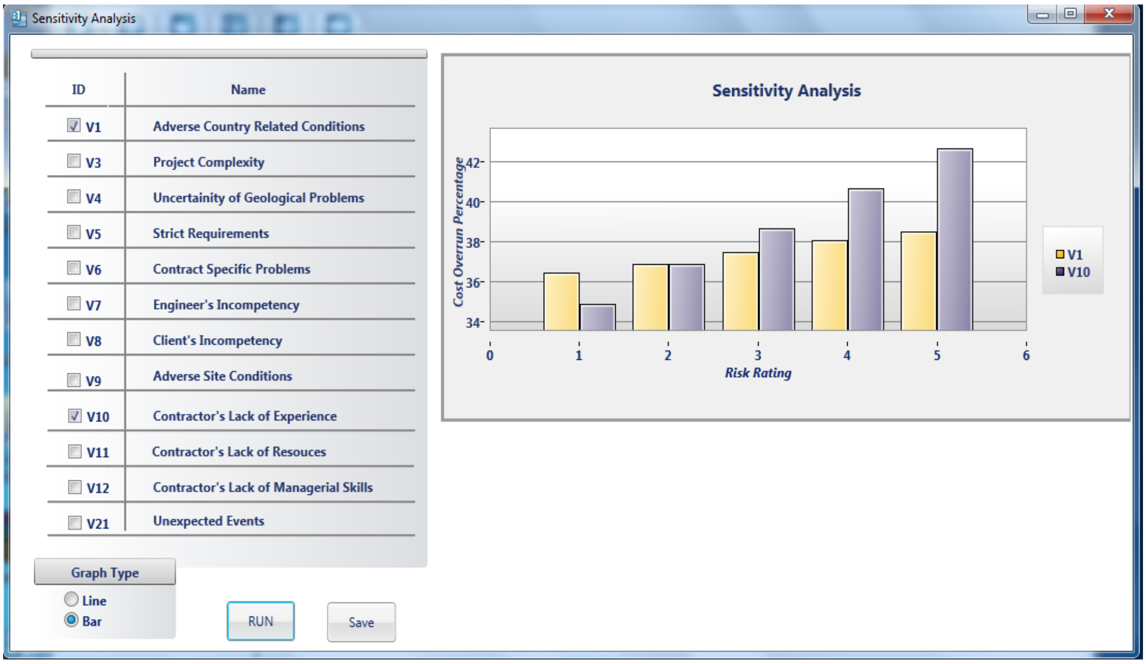

Figure 5.12: Snapshot taken from 'Sensitivity Analysis' interface

5.5.2. Automatic Report Generation System

'Automatic report generation system' documents and reports the risk assessment results and other documents (i.e. case results, sensitivity analysis) to enable decision makers to share these results or documents within the organization. The report generation system incorporates five major report types; (1) risk rating reports, (2) risk path impact report, (3) case report, (4) sensitivity analysis report, (5) cost overrun percentage reports. Cost overrun, risk rating, and risk path reports are the documentation of the results obtained through the risk assessment. Case report documents the past project cases that are retrieved from lessons learned database and reused within the assessment process. Documenting the project cases is essential in knowledge share and transfer phase of the knowledge management process. Finally, sensitivity analysis report documents the variations in the cost overrun percentage along with the selected vulnerabilities that are represented in a single line chart or a bar chart. In addition, the system documents the results within a structured template that is with the header and footer information. Header information of the documents include; project name, report name, report reference no. Footer information consists; company name, company address, company phone, and mail. In addition, decision makers could define default header and footer information with the use of report settings. Thus, this information will be retrieved whenever decision makers document the results.

5.5.3. Case Library

Case Library is provided to enable the examination of previous projects and associated cases that are stored within the lessons learned database previously. By facilitating knowledge storage, the case library is a part of the knowledge management system employed in the risk mapping tool.

5.5.4. Help Menu

A help option is provided to enable decision makers the better undestanting of the tool functions and terminology. The contents of the help option include; functions of the toolbar tabs (i.e.project, case, results etc.), methodology of the risk assessment process, terminology of the risk map, methodology of the sensitivity analysis, documentation of results, assigning attribute default weights, creation and use of lessons learned database.

CHAPTER 6

TESTING THE USABILITY OF THE RISK MAPPING TOOL

This chapter presents the evaluation of the usability of risk mapping tool through five main sections. In the first section the concept of usability and usability testing is overviewed. Second section introduces how the test plan of the usability testing is developed. Within the context of the test plan, it is decided to conduct laboratory testing sessions and questionnaires by the selected test participants. In the third section, the methodology for carrying out laboratory testing and preparing questionnaires is explained. In the fourth and fifth sections, findings and discussions of the laboratory testing and questionnaires are given, respectively.

6.1. The Concept of Usability and Usability Testing

6.1.1. Definition of Human Computer Interaction (HCI)

Usability is originated from the field called as Human-Computer-Interaction (HCI) (Carvalho, 2001). By focusing on the usability issues, it has been becoming one of the most significant fields in several research areas such as computer science and ergonomics (Helander et al., 1997). The idea of development of HCI initiated with the principles such as the developed artifacts should interest people, should provide easy and effective use of artifacts (Carroll, 2002). Hewett et al. (2009) defined HCI as “a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them”. HCI is also described as an interdisciplinary study focusing on the design and utilization of interactive technologies with the aim of improving usability and human acceptance of the systems (ACM SIGGHI, 2009). According to Preece (1993), the objectives of HCI include developing and supporting computer-based systems in order to conduct tasks safely, effectively, efficiently and enjoyable.

6.1.2. Definition of Usability

Usability is the key issue in human-computer-interaction and is related with the developing computer systems that are easy to learn and easy to use through conducting user-centered design process (Preece, 1994). The major driver of the acceptability of the educational software is its usability (Carvalho, 2001). According to Smith and Mayes (1996), currently usability is perceived as a significant variable in the success of computer-based systems and services since the inefficient systems could not sustain in the market. A number of definitions of usability from a variety of different sources are given in Table 6.1. In line with these definitions, the usability of a software or system can be measured by how the users can use the specific software and systems easily and efficiently with the given tasks in a defined test environment (Chapanis, 1991).

Table 6.1: Definition of usability in literature

Definition	Author(s)
"the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use"	ISO (9241-11)
"is the ease with which a software product can be used to perform its designated task by its users at a specific criterion."	Lin et al. (1997)
"is the capability in human functional terms to be used easily and effectively by the specified range of users, given specified training and user support, to fulfill the specified range of tasks, within the specified range of environmental scenarios".	Shackel (1991)
"a measure of the ease with which a system can be learned and used, its safety, effectiveness and efficiency, and attitude of its users towards it"	Preece et al. (1994)
"means that people who use the product can do so quickly and easily to accomplish their own tasks"	Dumas and Redish (1993)
"usability is related to the interface efficacy and efficiency and to user reaction to the interface."	Hix and Hartson (1993)
"The capability of the software product to be understood, learned, used, and attractive to the user, when used under specified conditions."	ISO/DIS 9241-11 (1996)
"The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use."	Boehm (1981)
"The ease with which a user can learn to operate, prepares inputs for, and interprets outputs of a system or component."	IEEE Std. 1061 (1998)

6.1.3. Definition of Usability Testing

Usability testing is a common technique to analyze user performance and to examine acceptance of products and systems (Wichansky, 2010). According to the author, even if it may not be the most efficient technique, it is still a reliable method to quantitatively measure performance of users and their subjective satisfaction with the products. According to Bastien (2010), usability evaluation (testing) is a way of ensuring that systems can be adapted and accepted by users. Hix and Hartson (1993) defined usability testing as "a process through which usability characteristics are specified, quantitatively and early in the development process, and measured throughout the process." For Ferre et al. (2001) usability testing describes the process of conducting usability tests in a laboratory with the test participants and recording the test results for further evaluations. Wichansky (2010) accepted usability testing as "any of those techniques in which users interact systematically with a product or system under controlled conditions, to perform a goal-oriented task in an applied scenario, and some behavioral data are collected". In accordance with the study of Lee (1999), usability testing ascertains how the system could meet with the predefined level of usability by the specified users conducting specified tasks. According to Dumas and Redish (1993) every usability test should consist of following five features; (1) specific goals should be defined, (2) test participants should be real users, (3) test participants should carry out real tasks, (4) facilitator should record what participants do and say, (5) facilitator should analyze the test results and suggest some changes to fix probable usability problems.

6.1.4. Attributes of Usability Evaluation

As the usability is "too abstract term to study directly" and has been used with different meanings, it is generally divided and represented with a set of independent attributes (Nielsen, 1993; Bevan and Azuma, 1997). In the field of usability testing, Lin et al. (1997) accepted eight human factor criteria; compatibility, consistency, flexibility, learnability, minimal action, minimal memory load, perceptual limitation, and user guidance. Nielsen (1993) described the usability by the means of five attributes, learnability, efficiency, memorability, errors and satisfaction. According to Ferre et al. (2001) usability consists of five attributes; learnability, efficiency, user retention over time, error rate and satisfaction. Shackel (1990) accepted four aspects of interest in usability testing: learnability (easy of learn), throughout, flexibility, and attitude. Booth (1989) outlined usability attributes as usefulness, effectiveness (ease of use), learnability, and attitude (likeability). For Smith and Mayes (1996) usability focuses on three aspects: easy to learn, easy to use and user satisfaction in using the system." In their study, Corry et al. (1997) accepted the usability attributes developed by Nielsen (1994); however, they considered efficiency and reduction of errors, as they are perceived as the most significant attributes. Guillemette (1995) identified usability attributes as; ease of learning, ease of use, few errors and system integrity, flexibility. Lindgaard (1994) specified usability attributes as; ease of learning, performance effectiveness, flexibility. Reed (1992) studied usability attributes in six sections; ease of learning, performance effectiveness, few errors and system integrity and user satisfaction.

6.1.5. Methods of Usability Evaluation

Within the available literature, several techniques have been used in the evaluation of usability problems of products. The widely used usability techniques are; field testing, laboratory testing, surveys, focus groups, thinking aloud sessions and questionnaires. According to Carvalho (2001), usability testing methods can be combined and utilized at the same time based on the project requirements and limitations as well as the technique for data collection;

According to Hameluck and Velocci (2001), the methods of evaluation of the usability of software applications fall into three categories namely; field testing, laboratory evaluation and beta testing. Within the context of the first method, field-testing, a trained usability tester is employed in a customer site to examine users facilitating the given software package. In this method, data gathering can be done with keeping notes of probable usability problems or incidents by the usability tester. In laboratory testing, users are enrolled in a usability lab in order to perform a list of pre-defined tasks. The data can be gathered by videotaping the sessions or by manually keeping the track of user problems in software use by usability tester. In beta testing, feedback on the usability of the given software package can be obtained from the users by conducting conference calls or surveys.

Ferre et al. (2001) distinguished major usability testing methods as; site visits, focus groups, surveys and derived data. Within the context of site visits, test facilitator observes tool users in their working environment and conducts some interviews to understand the perceptions of tool users. However, in focus group method, organized interview sessions are conducted with a selected group of tool users. Within focus groups, detailed information and experiences about a topic can be gained. When using the method of survey, it is essential to prepare questions in high quality since the quality of feedback depends on the distributed questions. The final method suggested by Ferre et al. (2001) is derived data, which includes hotline report, customer complaint letters etc. Although it can be a useful source, it only reports the problems and does not give any feedback about the features that tool users liked. Rubin (1994) listed usability techniques as; focus group, walk-through, paper-and pencil evaluations, usability audit, field studies, and follow-up studies. Preece (1993) classified usability evaluation methods as; expert evaluation (Heuristic evaluation), observational evaluation, survey evaluation and experimental evaluation. In expert evaluation method which also known as heuristic evaluation, experienced users in interface design and human computer interaction researches are requested to evaluate the probable usability problems they forecast for inexperienced users. Observational evaluation refers to the collection of data about what real users do when using software or a system. According to Preece (1993), surveys can be employed when the opinions or preferences of users about a product or a system is important. Finally, in an experimental evaluation, an evaluator detects a list of factors associated with an interface and examines the effects of the identified factors on user performance.

Lin et al. (1997) classified usability testing methods as; laboratory testing, thinking aloud, formal modeling, guidelines/checklists, and heuristic evaluation. Figure 6.1 demonstrates the summary of some benefits and shortcoming of different usability evaluation methods reported in Lin et al. (1997). To be noted that, authors comprehended and adapted the information given in Figure 6.1 from the studies of Nielsen (1993), and Lansdale and Ormerod (1994). Another study was carried out by Lee (1999) to identify methods of usability testing along with their advantages and disadvantages. Findings of the study of Lee (1999) are given in Figure 6.2.

Method name	Advantages	Disadvantages
Laboratory testing	• Identify serious problems; • Identify recurring problems; • Avoid low-priority problems; • Some degree of objectivity.	◆ Require expertise; ◆ High cost; ◆ Need large number of users; ◆ Miss consistency problems.
Thinking aloud	• Pinpoints user misconceptions; • Low cost.	◆ Unnatural to users; ◆ Hard for expert users.
Formal modelling	• Quantitative analysis; • Give unexpected insight; • Some degree of objectivity.	◆ Extremely complex; ◆ Require expertise; ◆ Tend to focus on one dimension.
Guidelines/checklists	• Identify general problems; • Identify recurring problems; • Can be used by non-specialists; • Applicable at all design stages.	◆ Miss some severe problems; ◆ Might be misapplied; ◆ Difficult to follow.
Heuristic evaluation	• Identify many problems; • Identify more serious problems; • Low cost; • Predict further evaluation needs.	◆ Require expertise; ◆ Require several evaluators; ◆ Some degree of subjectivity.

Source: Modified from Nielsen (1993) and Lansdale and Ormerod (1994).

Figure 6.1: "Summary of advantages and disadvantages of different usability evaluation methods" (Lin et al., 1997)

Method/Technique	Advantages	Disadvantage
Heuristic Evaluation Methods: To use a predefined list of heuristics to find usability problems	- Easy to learn and use - Inexpensive to implement - To identify problems early in the design process	- Debriefing session is necessary to find the indication of how to fix problems
Pluralistic Walkthroughs: To evaluate products from the perspective of the end-user.	- Easy to learn and use - To allow iterative testing - To meet the criteria of all parties involved in the test	- Difficult to find a proper context of task-performed for usability testing
Formal Usability Inspections: To test within the context of specific user profiles and defined goal-oriented scenarios	- To represent different knowledge domains - To get a list of problems and solutions for usability - To evaluate both cognitive processing and behavioral tasks	- Generally, end-users are not involved - Difficult to find a proper testing context of task-performed
Empirical Methods: An experimental test to prove or disprove a hypothesis.	- Effective for finding cause and effect - Effective for addressing a specific question or problem.	- Time consuming and expensive to conduct - Need to train a skilled practitioner
Cognitive Walkthrough: To test the ease of learning to use product by exploration	- Effective for predicting problems - Effective for capturing cognitive process	- Need to train a skilled evaluator. - Focused one attribute of usability
Formal Design Analysis: To test the understanding of the task requirements to be performed	- Adequate for analyzing a minimum of problem-solving behavior. - Effective for identifying problems in the early stage - Useful for comparing the different design of usability	- Difficult to learn and use - Only suitable for analyzing expert behavior.

Figure 6.2: Usability testing methods identified by Lee (1999)

6.2. Development of a Test Plan to Evaluate Usability of the Risk Mapping Tool

Within the existing literature, various researches accepted and followed a common usability-testing plan. Generally, the usability test plan or methodology consist of following issues; why, where, when, by who, how and for what to conduct usability test. According to Rubin (1994), a test plan may address "purpose of the test, problem statement or test objectives, user profile, method, task list, test environment and equipment requirements, monitor role, data to be collected and final report". According to Bastien (2010), development of usability testing generally requires following steps; (1) defining test objectives, (2) selecting test participants, (3) creating test scenarios and tasks, (4) identifying the measures and the way data will be captured, (5) preparing test materials and usability laboratory, (6) designing user satisfaction questionnaires, (7) presenting and discussing the test results. In this study, similar methodology is followed to prepare a usability test plan and conduct relevant test sessions; however, a more systematic approach is conducted to increase the reliability of the usability study.

6.2.1. Purpose of the Usability Test

According to ISO 9241-11, "the goal of a usability evaluation is to assess the degree to which a system is effective (i.e. how well the system's performances meet the tasks for which it was designed), efficient (i.e. how much resources such as time or effort is required to use the system in order to achieve tasks for which the system was design), and favors positive attitudes and responses from the intended users ". In this study, the objective of usability testing is to ensure that the proposed risk mapping tool could be used by decision-makers effectively and quickly. It is also aimed to propose a tool that satisfies the needs of decision-makers, improves the competency of decision-makers through tool experience, and guides them when carrying out tool functions. Although, the tool is developed in line with these purposes, this may not be an actual case in real operations. In this study, it is argued that usability level of the tool is as significant as the quality and quantity of functions that tool facilitates or the accuracy of risk assessment results quantified by the tool. In this study, it is argued that, the functions and capabilities of the tool are helpful in the extent of their usability and the acceptance by decision makers. In addition, it is believed that, the knowledge of the encountered usability problems is significant to implement some suggestions to avoid probable future problems. The major purposes of conducing usability testing are; (1) measuring the user performance when using the tool, (2) identifying the user satisfaction after using the tool, (3) understanding the user perception on global issues.

6.2.2. Usability Testing Objectives and Evaluation Techniques

Based on the major purposes of the usability testing, two objectives are identified as critical measures in the evaluation of the usability of the risk mapping tool. These are quantitative objectives to measure user performance, and qualitative objectives to understand user satisfaction and perception. According to Smith and Mayes (1996), based on the defined test purpose, quantitative data can be collected such as time required to participants to understand a function, or qualitative data such as participant attitude towards the function. According to Carvalho (2001), tests should also address user performance and satisfaction. In this study, it is argued that, quantitative objectives should respond to the ease and quickness of test participants when using the risk mapping tool. However, qualitative objective are mostly related with the satisfaction and perception of test participants on general view, interfaces, and functions of the tool. Through developing quantitative and qualitative objectives, it is aimed to evaluate the overall usability of the risk mapping tool. However, some set of techniques should be developed to gather information about these objectives and evaluate the usability of the tool. It is argued that, some usability measures and attributes should be developed in order to evaluate test findings systematically and compare the results of usability with the targeted measures.

6.2.2.1 Usability Attributes

Within existing literature, various researchers accepted a set of attributes for the evaluation of overall usability level of their systems/software/websites. As it was given in previous section of this study, some of these attributes are; compatibility, consistency, flexibility, learnability, minimal action, user guidance, efficiency, memorability, errors and satisfaction, usefulness, effectiveness and attitude (likeability). In this study, the most significant and applicable usability aspects of the risk mapping tool is identified. In accordance with these aspects, seven usability attributes are selected to address these aspects as well as to represent overall usability level of the tool. The selected usability attributes are; ease of use, effectiveness, satisfaction, consistency, learnability, user guidance, and error rate.

Ease of Use: In this study, ease of use represents number of participants who completed all tasks of laboratory testing satisfactorily. It also consists, participants' decision on the easiness on the tool interfaces and easiness of using the tool.

Effectiveness: Effectiveness is the level of user performance that can be measured by means of speed and error rate (Lindgaard, 1994; Shackel, 1991). According to Ferre et al. (2001), it is a quantitative measure in the ease of using the system, and "the number of tasks per unit time that user can perform using the system". Usability of a system is directly proportional with the quickness of user in performing and completing tasks (Ferre et al., 2001).

Satisfaction: Satisfaction represents the users' subjective decision, impression, feeling, and perception about the system (Ferre et al., 2001). According to Lindgaard (1994), systems and software should be enjoyable to use and aesthetically pleasing to users.

Consistency: According to Lin et al. (1997), consistency can enhance user performance and satisfaction. Grudin (1989) classified consistency as internal and external. While internal consistency represents consistency within a system, external consistency is the consistency among different systems. In this study, only the internal consistency is included within the usability studies.

Learnability: Learnability is the measure of how easy it is to learn the functions of the main system and gain competency to complete the tasks (Ferre et al., 2001). According to Lindgaard (1994), "learnability is the ease with which new or occasional users can complete certain tasks". For Lin et al. (1997), learnability can be enhanced if well-designed and well-organized interfaces are presented to users.

User guidance: According to Lin et al. (1997), well-prepared and sufficient user guidance will enhance the learnability of the computer systems as well as minimize the mental workload of system users. User guidance represents how the help option is useful when participants used help.

Error rate: Error rate does not represent the system errors. It refers to the number of errors the user makes when conducting a specified task. High level of error rate reduces the efficiency of the system and satisfaction of users (Ferre et al., 2001). In this study, error rate represents the number of problems participants encountered while conducting tasks of laboratory testing.

6.2.2.2. Quantitative Objectives

The first objective of the usability testing is to measure the efficiency and performance of the participants when using the risk mapping tool. According to Carvalho (2001), "performance data correspond to measures of participant behavior, focusing on aspects such as "efficiency and efficacy of use". It may measure, 'error rates', 'time to perform a task', 'number and percentage of tasks completed incorrectly', 'time spent reading a specific section', 'count of incorrect menu choices', 'count of incorrect icons selected', 'count of negative comments', etc. In this study, quantitative objectives are defined to explore the four usability attributes; ease of use, effectiveness, learnability, and error rate. In addition, based on the quantitative objectives, some usability measures are developed to evaluate the user performance in tool use. These measures will further be used in laboratory testing in order to quantify the performance of test participants when carrying out tasks.

Table 6.2 demonstrates the usability measures identified and utilized in this study, as well as expected usability goals and attributes associated with them. According to Ferre et al. (2001), in order to analyze the value of the usability attributes, it is required to define a set of usability benchmarks for each attributes that represent quantitative usability goals. Authors added that, these benchmarks should be defined in a way that they could be calculated in a usability test or with a user satisfaction questionnaire. Within this context, to develop usability benchmarks for each of the usability measures, a pilot testing study is conducted with the test facilitator who is experienced in risk mapping tool. The pilot study and the defined usability benchmarks will be introduced in the further sections of the study.

Table 6.2: Quantitative usability measures

Usability Measure	Data Source	Usability Attribute	Usability Goal
number of participants who successfully completed a task	Laboratory Testing	Ease of Use	Is it easy to use the tool?
amount of task completion time of each inexperienced participant	Laboratory Testing	Effectiveness	How the inexperienced participant is efficient in using the tool?
amount of task completion time of experienced participant	Laboratory Testing	Learnability	How the experienced participant is efficient in using the tool? In what extent, the participant learns to use the tool.
amount of mouse clicks of each participant in conducting each task	Laboratory Testing	Ease of Use	How the participants are efficient in using the tool?
number of help use during conducting each task	Session Audit	Ease of use /User Guidance	Is it easy to use the tool without help? How the help option is useful?
number of problems/reworks encountered in conducting each task	Session Audit	Error Rate	What type of problems participants' encountered?

6.2.2.3. Qualitative Objectives

The qualitative goals are distinguished as; examination of user satisfaction and perception on global issues and specific functions of risk mapping tool. User satisfaction demonstrates the measures of participant opinion and comprises response data such as participant ranking, and answers to questions (Carvalho, 2001). Some measures of user satisfaction are; usefulness of the product, the ability of the product to match with the expectations, overall ease of use, overall ease of learning, ease of accessibility and so on (Rubin, 1994). In this study, qualitative objectives are identified to investigate the five attributes; ease of use, satisfaction, consistency, learnability, and user guidance. To be noted that, some attributes (i.e. ease of use, learnability etc.) are also measures quantitatively through laboratory testing. However, with conducting post-test questionnaires, subjective responses of participants on these attributes are gained. Structure of post-test questionnaires and their findings will be introduced in the further sections.

6.3. Methodology for Testing the Usability of the Risk Mapping Tool

Based on the qualitative and quantitative objectives, the usability testing is conducted within two parts; carrying out laboratory testing with pre-defined task scenarios and conducting post-task and post-test questionnaires. Firstly, the test participants are selected who are appropriate to involve in usability testing process. As a second step, the test scenarios and associated tasks with these scenarios are identified based on the major functions of the risk mapping tool. Based on the pre-defined usability attributes, set of post-test questionnaires are developed in order to capture user satisfaction and performance. Prior to the laboratory testing, initially a pre-training session is conducted with the participants in order to provide brief information about the usability testing process and the risk mapping tool. Laboratory testing is conducted to measure the level of efficiency and quickness of the test participants when conducting the predefined test scenarios and tasks. The laboratory testing sessions are conducted within two parts. Firstly, a pilot testing is carried out with the collaboration of a participant experienced in using the risk mapping tool. The objective of pilot testing is to evaluate the applicability of the tasks and questionnaires as well as to derive a best estimate times for each task. After the pilot testing, laboratory testing is conducted with the selected participants to obtain quantitate measures of the test goals. Post-task questionnaires are conducted after participants are completed each of the laboratory testing tasks. After each participant completed test scenarios and tasks, a final post-test questionnaire is conduced to capture their perception on the tool. Final stage is the gathering of both quantitative and qualitative data to evaluate the usability level and problems of the risk mapping tool. The usability testing procedure can be summarized as; (1) selecting test participants, (2) designing task scenarios, (3) establishing questionnaire, (4) conducting pre-test training, (5)conducting pilot testing, (6) conducting laboratory testing, (7) conducting questionnaire, (8) evaluating the results. Table 6.3 summarizes the usability testing methodology employed in the usability study through comprehending test objectives, usability attributes, and measurement techniques.

Table 6.3: Summary of usability testing methodology

Test objective	Usability Attributes	Measurement Technique	Description
Quantitative Objectives	Ease of Use, Effectiveness, Learnability	Laboratory Testing	Tobii Software records the usability measures and eye tracks of participants
	Ease of Use, User Guidance	Session Audit	Test facilitator records number of help use of each participant.
Qualitative Objectives	Error Rate	Session Audit	Test facilitator records user problems in tool use during laboratory testing sessions.
	Ease of Use, Satisfaction, Consistency, Learnability, User Guidance	Post-Task Questionnaire	Participants fill out questionnaire after they completed the given tasks
	Satisfaction	Post-Test Questionnaire	Participants fill out questionnaire after they completed all tasks.

6.3.1. Development of Test Scenarios and Tasks

To measure the user performance when using the risk-mapping tool, laboratory-testing sessions are conducted by test participants. Within the methodology of the laboratory testing, firstly test scenarios and tasks are identified which will be conducted by test participants in test sessions. The test scenario describes "a fictional story of a user interacting with the system in a particular situation" (Ferre et al., 2001). Based on the major functions of the risk mapping tool, a set of test scenarios and tasks are developed to provide information about the qualitative objectives of the usability study. These objectives and their usability measures are given in previous section of this study. In this chapter, how the tasks are selected and what they will measure, will be introduced.

In this study, test scenarios and associated tasks are developed with the consideration of which functions of the tool is mostly important or mostly used. As the available times of participants are limited, the most critical, and significant operational steps in tool use are involved in laboratory testing. As was discussed in the previous chapters of this study, the major aim of the risk mapping tool is carrying out risk assessment with the assistance of vulnerability source attributes and/or lessons learned database. In addition, tool can also be used to capture previous project knowledge to develop an organizational lessons learned database. These functions of the tool constitute the major framework of the test scenarios;

however, some less significant but necessary functions are also incorporated into the development of test scenario process. For instance, entry of project information is a simple and straightforward process; however creating a new project is necessary action to carry out following steps. In addition, it is argued that, those interfaces, which contain significant information (i.e. visualization of results) and graphical information (i.e. sensitivity analysis), should also be put into use, thus scenarios/tasks utilizing these interfaces are also developed. Nine major scenarios are derived from the operational steps in tool use and utilized in laboratory testing. These operations are; (1) creating a project, (2) assigning attribute default weights, (3) using attributes, (4) using lessons learned database, (5) using risk map, (6) evaluating, and reporting the results, (7) using sensitivity analysis, (8) assigning a new case, (9) using the case library. In addition, each scenario consisted of a list of tasks all associated with the concept of the scenario and are required to carry out each scenario. The detailed descriptions of each scenario and associated tasks are given in Appendix C. However, the summary of these scenarios and their related tasks are given in Table 6.4.

Same task scenarios are given to the participants in order to keep consistency of the test. Although, it is not aimed in the context of the usability test to carry out risk assessment and quantify cost overrun percentage of a project, task scenarios mostly require previous project information and data as an input. Although, participants can utilize their individual experience regarding their previously completed projects, a sample project data is given to the participants to use them as inputs. This is due to two major problems in utilizing individual experience. Firstly, participant may not have any information or quantitative data regarding their previous projects due to having limited occupational experience. The second consideration is; even if participants have sufficient experience, it may be hard or take considerable time to remember project information or difficult to utilize quantitative data of previous projects. As it is out of the scope of usability test to evaluate risk level of real construction projects, it is insignificant to utilize real data of previous project. Thus, it is not reliable to record the time taken to the evaluation of quantitative data when carrying out the tasks. With the consideration of above-mentioned problems, a sample project data is distributed to the participants. The detailed descriptions of test scenarios and tasks along with the sample project data is given in Appendix C.

Table 6.4: Laboratory testing scenarios and associated tasks

Test Scenario	Task
Scenario 1: Ease of creating a project	Task 1: Assign project information
Scenario 2: Ease of assigning attribute default weights	Task 1: Assign default attribute weights
Scenario 3: Ease of using attributes	Task 1: Use default attribute weights
	Task 2: Use equal attribute weights
	Task 3: Assign attributes weights and ranking manually.
Scenario 4: Ease of using lessons learned database	Task 1: Open lessons learned database
	Task 2: Refine project cases
	Task 3: Search keyword
	Task 4: Assign the rating retrieved from lessons learned database
Scenario 5: Ease of using risk map	Task 1: Assign ratings of vulnerabilities
	Task 2: Run risk assessment
Scenario 6: Ease of evaluating results	Task 1: Open risk rating result
	Task 2: Open risk paths result
	Task 3: Open cost overrun result
	Task 4: Report the risk rating result
Scenario 7: Ease of using sensitivity analysis	Task 1: Select one vulnerability and select bar chart
	Task 2: Select two vulnerabilities and select line chart
Scenario 8: Ease of assigning a new case	Task 1: Add new case
Scenario 9: Ease of using the case library	Task 1: Search project information and case

6.3.2. Development of Checklists for Expert Session Audit

To capture the instant actions and formative evaluations of the test participants, it is discussed to either carry out think aloud method or conduct session audit by test evaluator. Within the context of the first procedure, it is required from participants to think aloud when conducting tasks in order to verbalize their actions and collect the probable problems (Ferre et al., 2001). On the other hand, it is argued that, this method may adversely affect the efficiency of the participants since it is required them to conduct tasks and state decisions at the same time. Thus, it is decided manually keeping the track of problems that participants encounter in laboratory testing sessions by test facilitator. To capture the probable problems by test facilitator, a checklist is prepared that consists following usability questions;

- Is the participant able to complete the task?
- Is the participant encountered any problem in tool use?
- If yes, what are these problems?
- Is the participant used the help option of the tool?

6.3.3. Development of Post-Task Questionnaires

As the laboratory testing sessions provide quantitative data about the performance of each participant in carrying out the tasks, the qualitative information about the participants' perception and satisfaction regarding each task remains. Thus, to understand the user satisfaction in tool use, several questionnaires are prepared to be conducted by test participants after they completed the each of the given test scenarios. These questionnaires are developed in accord with the identified usability attributes (i.e. ease of use, satisfaction, etc.) and will be used to evaluate subjective responses of participants on these attributes. According to Carvalho (2001), in the case of existing questionnaires are applicable to the particular task, they can be used to evaluate user satisfaction; if they are not then new questionnaire can be created to fit the task. In this study, it is discussed that, the existing questionnaire should be modified to obtain specific information pertaining to the test objectives. Thus, the post-task questionnaires are prepared by modifying the standard post-test questionnaires that are widely recommended in literature and widely facilitated by several authors to evaluate user satisfaction. The study of Lund (2001), Lin et al., (1997), Davis (1989), Chin et al. (1988), and Lewis (1995) are the major references for the development of questionnaires. Most of these questionnaires are designed in accord with the identified usability attributes and they provide information about each attribute separately. The detailed information these questionnaires are given in Table 6.5. Within these studies, questionnaires used to give feedback about the general view or the use of the system, software, or websites. In this study, it is argued that having a general feedback by a single questionnaire may underestimate the specific usability problems that may arise when conducting tasks. In addition, it is probable that, participants encounter with a problem, or dissatisfied with an interface or functions; even if they perceive overall tool use or tool design as satisfactory. For instance, participants may not learn how to use a function of the tool even if they perceive learnability of the overall system as satisfactory. In this case, it is highly probable that, the participant will rank the learnability attribute of the tool as satisfactory, although he/she could not learn to use the specific task. Thus, capturing the overall perception of participants by a single questionnaire may give misleading results and underestimate the usability problems regarding the specific tasks or tool interfaces. To collect more specific participant responses and to have a deep understanding about the usability problems, separate questionnaires for each test scenario and tasks are prepared. In addition, instantly capturing the feedbacks about the tool experiences of participants is significant to ensure participants completely remind their actions.

Table 6.5: Sample questionnaires

Questionnaire Name	Author	Number of Items	Scale	Identified Usability Attributes
QUIS (Questionnaire for User Interface Satisfaction)	Lund (2001)	30	7	Usefulness, Ease of Use, Ease of Learning, Satisfaction
Purdue Usability Testing Questionnaire	Lin et al. (1997)	100	7	Compatibility, Consistency, Flexibility, Learnability, Minimal Action, Minimal Memory Load, Perceptual Limitation, User Guidance
Perceived Usefulness and Ease of Use	Davis (1989)	12	7	Perceived Usefulness, Perceived Ease of Use
Questionnaire for User Interface Satisfaction	Chin et al. (1988)	27	9	Overall Reaction to the Software, Screen, Terminology and System Information, Learning, System Capabilities
Computer System Usability Questionnaire	Lewis (1995)	19	7	-

The post-task questionnaires involve subjective responses of participants on usability attributes and the perceptions of participants on risk mapping tool functions by utilizing 1-5 likert rating scale. 'One' demonstrates strongly disagree preference of participants while 'five' indicates strongly agree. In addition, the responses of questionnaires are used to compare and evaluate what participants think about the tool and what they actually do in task use. The statements taken from post-test questionnaires are given in the further section of this study when giving the findings of these questionnaires. During laboratory testing sessions, it is required from participants to provide a rating for the usability attribute concerning the completed test scenario and tasks. To be noted that, although it is required from participants to fill these questionnaires after they completed each task, time taken to conducting questionnaires are not included as the task completion time. The actual task completion times are obtained by Tobii Studio, by selecting only the time frame falling between task initiation and task completion times. As a summary, with the incorporation of post-test questionnaires, user perception pertaining to each of the laboratory testing tasks can be gathered and evaluated in addition to the quantitative information obtained from laboratory testing sessions.

6.3.4. Development of Post-Test Questionnaire

As the post-task questionnaires are specifically referred to the task experiences of participants, the global aspects (i.e. overall tool satisfaction) were remained unanswered. Thus, the post-task questionnaire is designed to give information about the global issues about the tool use and to evaluate satisfaction level of test participants. These questionnaires provided insight into the decisions and feelings of participants in tool use and suggestions through the tool use experience. In addition, these questionnaires provided participants the opportunity of expressing missing clauses and issues (those they could not addressed in laboratory testing or post-test questionnaires) regarding the tool use. It utilizes free-form response questions including following issues;

- What do you like most about the tool?
- What do you like least about the tool?
- Is there any task that is difficult for you to do?
- What else should be included on the tool?
- Are you satisfied with your experience using the tool?
- Would you like to make any comments or suggestions about the tool?
- If the tool were available in market, how likely would you use tool it?
- If you are not likely to use the tool, why?

6.3.5. Selection of Participants

Test participants are selected with the consideration of two issues; (1) sample size, (2) sample knowledge. In addition, selected participants are further divided into two groups as those experienced and inexperienced in tool use.

Sample size: Through the review on the existing literature, it is understood that, determination of the sample size is depend on diversity of the tasks and complexity level of the systems (i.e. software, tool, and website). Within literature, a sample size criterion developed by Nielsen (1993) and Virzi (1992) has been widely accepted and facilitated by various authors. According to Nielsen (1993) and Virzi (1992), the sample size between four and five participants can effectively detect 80% of the usability testing problems. However, a more recent study conducted by Faulkner (2003) revealed that, five participants could only detect 55% of the usability problems. In his study, Faulkner (2003) conducted several tests with the varying sample size to investigate in what extent the selected size can detect usability problems. The major finding of him is; increasing the sample size from five to ten could extremely increase the confidence level of the test results. The findings of this study are given in Figure 6.3. In this study, as the objective of the usability testing is to evaluate the generic problems/concerns that will emerge in tool use, it is argued that the sample size of eight is appropriate. It is believed that, with the involvement of eight participants, most of the common usability problems of the risk mapping tool can be detected. Thus, eight participants are selected and involved in the usability testing process. During usability test, they are scheduled over the two consequent testing dates.

No. Users	Minimum % Found	Mean % Found	*SD*	*SE*
5	55	85.55	9.2957	.9295
10	82	94.686	3.2187	.3218
15	90	97.050	2.1207	.2121
20	95	98.4	1.6080	.1608
30	97	99.0	1.1343	.1464
40	98	99.6	0.8141	.1051
50	98	100	0	0

Figure 6.3: "Percentage of Total Known Usability Problems" (Faulkner, 2003)

Sample knowledge: According to Carvalho (2001), participants should be representative of the target population to analyze in what extent a product achieves specific usability criteria. The proposed tool is developed for construction practitioners (i.e. contractors, engineers, or clients) to evaluate the risk level of their construction projects or their previous risk-related knowledge of previous construction projects. Thus, the target population of the tool is construction practitioners that can be civil engineers, project managers, or architectures. In addition, as the terminology of the tool is related with the field of construction risk management, it is required to select participants who are slightly knowledgeable in construction engineering and management. Thus, participants who are graduated from civil engineering department of METU are selected to involve in usability studies.

Sample experience: After participants are selected based on the consideration of sample size and characteristic, they are requested to fill a pre-test questionnaire to gather the background information about them. Conducting pre-test questionnaire provided a glimpse about issues such as the participants' computer use experience, the frequency of use of computer software, etc. In addition, according to Carvalho (2001), individual characteristics and differences of the participants are significant issues for usability testing. Author classified participant experiences as; experience with the system, with the computer in general, and with the task domain. It is known that, all participants are experienced in computer system and none of the participant has any experience about the risk mapping tool as well as the task domains. However; to understand the degree of which participants can learn to use the tool and learn to perform the given tasks, participants are classified into two distinct groups. First group consist only one participant and a detailed pre-training sessions is provided to the participant to explain and show the tool functions in detail. For the second group, a limited training session is provided with the aim of giving brief information about the tool. The detailed descriptions of the participants, which are captured from the pre-test questionnaire, are given in Table 6.6. The responsibilities of participants cover completing the task scenarios that are presented to them in as efficient as possible, as well as participating in post-test and post-tasks questionnaires and providing feedback on the presented questions. Participants were equally involved in the sessions and they all successfully completed the given test scenarios.

Table 6.6: Participant characteristics

ID	Gender	Age Group	Education (current)	B.Sc. Grad.Date	Computer Experience	Frequency of software use
P1	Male	18-24	PhD	2009	16 years	Daily
P2	Female	18-24	M.Sc.	2010	12 years	Daily
P3	Female	25-34	PhD	2007	10 years	Monthly
P4	Male	18-24	M.Sc.	2012	12 years	Daily
P5	Male	18-24	M.Sc.	2012	15 years	Daily
P6	Female	25-34	PhD	2008	15 years	Daily
P7	Male	25-34	PhD	2008	16 years	Weekly
P8	Male	18-24	M.Sc.	2010	16 years	Weekly

6.3.6. Test Environment and Equipment

The laboratory testing is take place at METU Computer Center, Human Computer Interaction Research, and Application Laboratory. The laboratory was developed in 2006 with the aim of facilitating usability tests that are conducted to develop user-friendly, effective, and efficient interfaces. The laboratory is accredited with the "TS EN ISO/IEC 9241-151 Ergonomics of Human-System Interaction - Part 151: Guidance on World Wide Web User Interfaces" standard as well as the "ISO/IEC 17025 General Requirements for the Competence of Testing and Calibration Laboratories" standard of TSE. The laboratory gives four major services; it provides laboratory environment for academic, public and private sector researches, it provides usability consultancy, it provides full usability testing, and provide eye-tracking facility. The full usability testing service of the laboratory includes;

expert review, satisfaction questionnaire, eye movement analysis, performance analysis (task completion time and number of errors and steps), and recommendations. By serving usability studies, laboratory provides feedbacks about the user’s perception to the interfaces at the software design stage as well as the problems that user encounter after the design stage. It enables to get feedback of experiment results by recording the image of the users, their eye movements, and monitoring the snapshots of the tested software in order to evaluate the applicability of the software. In order to utilize these services, the laboratory serves some high quality and equipped devices and software packages that are located either on the experimentation or control room involved in the laboratory. During the usability test sessions, some specialized equipment and software are used. The list of equipment and software and their functions are given in Table 6.7.

Table 6.7: Test equipment and software

Equipment/Software	**Function**
The Camera Recorder-1	Used to record the face of participant
The Camera Recorder-2	Used to record the key board activity of the participant
The Eye Tracker (Tobii T120)	Used to collect data about where on the screen the participant looks, how long a glance is, how many times the participant looks at a certain point on the screen. It also records all the eye movements of the participants on the screen.
Test Computer	Used by participant and attached to the eye tracker. It records the onscreen view of the participants.
Tobii Studio	Tobii Studio is software that transforms the information recorded from the reflectors, the infrared detector cameras into visual and digital data.

6.3.7. Pilot Study

A pilot testing prior to the usability test sessions is conducted to evaluate whether the task scenarios are appropriate and usability questions are suitable. Pilot testing is conducted with test facilitator who is experienced in using the risk mapping tool. To be noted that, the facilitator conducting the pilot test is not recorded as test participant. Pilot testing is used to determine the best estimate time for each task scenario. During the pilot test session, time taken to conduct each task is recorded and accounted as the best estimate time to complete each task. Best estimate times are further be used to compare time taken the inexperienced and experienced participants to complete tasks. Comparing these times is significant to understand in what extent the competency on using the tool is important in the performance times. In other words, it provides the evaluation of in what extent the tool is usable by the incompetent participants. To be noted that, in each test session, unlimited time is given to participants to complete the tasks, and tasks are not considered as unsuccessful even if participants could not conducted the task scenarios in the best estimate time. With the use of best estimate times, quantitative usability benchmarks are simply identified by doubling best estimate times. Pilot study results will be given in the further sections of this study along with the all laboratory-testing results.

6.3.8. Usability Benchmarks

To define usability benchmarks for the measures of laboratory testing, a pilot study was carried out by test facilitator. The best estimate times recorded during the study was doubled and defined as acceptable level allotted to each measure. In addition, it is accepted to define ease of tool use as satisfactory if all participants can successfully complete all tasks. The maximum help use rate for each participant defined as 30% in order to call as satisfactory. Error rates measure the number of problems that participants encounter while conducting the tasks. There are no benchmarks for the error rate since it was utilized in laboratory testing sessions to capture the problems that hinder the usability of the tool. Finally, for all questionnaires, average participant response should be minimum four from five in order to call associated usability attributes as satisfactory. Table 6.8 demonstrates usability benchmarks along with the usability attributes, measures, and measurement techniques.

Table 6.8: Usability benchmarks

Usability Attribute	Measurement Technique	Usability Measures	Usability Benchmarks	
			Best Estimate	Acceptable Level
Ease of Use	Laboratory Testing	Completion Rate	-	100%
Effectiveness	Laboratory Testing	Total Visit Duration	673.98	1347.96 s
Ease of Use	Laboratory Testing	Mouse Click Count	237	474
Ease of Use	Sessions Audit	Help Use	-	30%
Ease of Use	Sessions Audit	Error rate	-	-
Ease of USe	Post-Task Questionnaire	1-5 Likert Scale	-	4
Satisfaction	Post-Task Questionnaire	1-5 Likert Scale	-	4
Consistency	Post-Task Questionnaire	1-5 Likert Scale	-	4
Learnability	Post-Task Questionnaire	1-5 Likert Scale	-	4
Minimal Action	Post-Task Questionnaire	1-5 Likert Scale	-	4
User Guidance	Post-Task Questionnaire	1-5 Likert Scale	-	4
Satisfaction	Post-Test Questionnaire	-	-	-

6.3.9. Pre-Test Training

A pre-test training session is conducted to give brief information about the risk mapping tool, and overview the usability test procedure. Firstly, the tool is introduced to the participants by reviewing its major functions in order to provide a basic knowledge of the tool. As a secondary step, the usability testing procedure and the task scenarios that should be performed by the participants is explained. Since the participants have not been specifically experienced in the field of risk management, during the usability testing process the task scenarios may be difficult for participants to understand what each task scenario requires. To be noted that, the time taken to the reading of tasks is not recorded as performance time. In the third step, the equipment that is used in the usability test is introduced. As a concluding remarks in pre-test training session, it is stated to participants that, within the scope of the usability test some measurements (i.e. the amount of time allocated to finish the task scenarios, the eye movements when carrying out each tasks) will be recorded during laboratory testing sessions.

6.3.10. Laboratory Testing Sessions

The usability testing is structured within four major phases; (1) filling pre-test questionnaire, (2) conducting laboratory test, (3) filling post-task questionnaire, (4) filling post-test questionnaire. The first phase was given in previous section. The most significant and critical phase is the conducting laboratory test. Thus, developing a well-structured testing methodology has a vital role on the effectiveness and reliability of the findings of the laboratory tests.

Within existing literature, several techniques are offered to carry out during laboratory testing sessions. One of the most utilized techniques is carrying out think-aloud sessions within which participants are requested to interpret their decisions and actions loudly. As was mentioned in the previous sections of the study, although thinking-aloud enables capturing the problems user faced or the subjective responses and decisions of participants about the task, it may suffer from taking considerable effort and time when conducting tests. Another technique is facilitating paired-user testing in which two participants conduct tasks together. Although, the technique is beneficial by supporting a natural interaction style and capturing more responses and comments from the participants, collaboration of participants from diverse learning, verbal and cultural styles may hinder the reliability of the feedback (Bastien, 2010). In line with these considerations, during test sessions, the tasks are given to the participants one by one as well as session audits are incorporated by the test facilitator to keep the track of user problems and errors. The facilitator is observed and maintained participant behavior and comments to enable better understanding of the usability problems. For every task, information such as success or no success on completion of relevant tasks, number of errors or problems, and time taken to complete each tasks was kept by the test facilitator. The qualitative information regarding each task is also kept by the Tobii Software. When the test participants are completed each task, they are asked to fill post-task questionnaire. After all tasks have been completed, the participants are required to complete a post-test questionnaire. In addition, eye trackers are incorporated during testing process to obtain visual data about the each task. Eye movements of participants are recorded by Tobii T120 and analyzed with Tobii Studio Software. The eye tracker captures data such as where the participant looks on the screen, how long a fixation is, how much time the participant looks at a certain point on the screen, and all the eye movements of the participant during the testing.

6.4. Findings and Discussions of the Laboratory Testing

6.4.1. Findings and Discussions of Quantitative Data

Quantitative results of laboratory testing are obtained into two metrics; total visit duration and mouse click counts. Total visit duration is the duration of all visits of a participant within the specified task. It gives the time taken to completion of specified task by the test participant. It is recorded for each task separately and for each participant. It answers the usability measures of ‘amount of task completion time of each inexperienced participant’ and ‘amount of task completion time of experienced participant’. In addition, mouse click counts of each participant in each task, also recorded as part of quantitative objects. Mouse click count refers to the number of times the participant left-clicks with the mouse when conducting the given task. It answers the usability measure of ‘amount of clicks of each participant in conducting each task’. Please refer Table 6.2 to examine the quantitative objectives of laboratory testing. The recordings of the ‘total visit duration’ and ‘mouse click count’ are given in Table 6.9, Table 6.10, respectively. P0 represents the pilot study of the test facilitator, and it gives the best estimate time or count values. Allotted time or counts are also given that are the double of the best estimate times. Test participants are denoted as P1, P2 etc. and the experienced participant is the fifth participant (P5). The findings of the fifth participant reveal that, with a single tool training session the effectiveness of the users can be considerably improved. Thus, the tool can be regarded as learnable through experiencing its functions. Within these tables, the values that exceed the allotted time or mouse click count are represented in red. In addition, some descriptive statistics (i.e. mean, maximum, etc.) of the test results for each task are given in these tables. To be noted that, as the test facilitator is not the representative of usability testing, pilot study results are not included in calculation of descriptive statics. In addition, summary of the laboratory testing findings are given in Table 6.11 and Table 6.12. These tables represents amount of time or number of counts allotted to each task, observed average, best and worst results of each task. The values exceeding the allotted time or counts are again represented in red. Although, in some of the tasks, two participants exceeded the allotted times or click counts, they finished the whole test within the allotted total visit durations and total click counts. In addition, worst observed visit durations are generally larger the time allotted to each task, average visit durations of participants are less than the allotted times except scenario 4- task 3 and scenario 6- task 4. For the mouse click counts, all observed average and best values are less than the count allotted to each task. In this study, it is argue that average results are significant while analyzing the overall ease of tool use. Thus, the usefulness of the tool and efficiency of participants when using the tool, are accepted as satisfactory.

Table 6.9: Total visit duration

Total Visit Duration															
Scenario	**Task**	**P0 (pilot study)**	**Allotted Time**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**Mean**	**Max**	**Min**	**StDev**
1	**1**	81.28	162.56	139.71	121.79	**176.6**	141.17	97.89	117.21	160.55	126.63	135.19	176.6	97.89	25.02
2	**1**	51.86	103.72	100.86	71.47	83.89	64.58	59.82	101.1	**117.05**	89.04	85.98	117.05	59.82	19.93
3	**1**	38.74	77.48	62.33	76.71	62.59	62.52	52.58	**84.95**	**85.51**	67.1	69.29	85.51	52.58	11.87
	2	29.6	59.2	30.39	48.38	45.6	38.75	21.6	36.16	45.25	46.32	39.06	48.38	21.6	9.28
	3	23.91	47.82	41.82	26.07	40.24	39.28	19.56	37.06	33.69	37.74	34.43	41.82	19.56	8.06
4	**1**	34.23	68.46	**91.23**	**99.47**	**73.06**	**74.5**	35.45	37.95	68.92	**71.29**	68.98	99.47	35.45	22.57
	2	17.19	34.38	23.23	12.45	16.1	17.76	22.88	16.66	19.2	16.27	18.07	23.23	12.45	3.62
	3	13.66	27.32	**37.59**	16.06	**30.37**	**35.42**	22.39	34.21	**68.88**	31.28	34.53	68.88	16.06	15.62
5	**1**	124.64	249.28	214.39	161.06	**255.12**	149.12	125.87	164.63	154.9	130.72	169.48	255.12	125.87	43.88
	2	9.94	19.88	10.71	9.31	16.11	14.67	10.17	14.39	11.46	11.17	12.25	16.11	9.31	2.46
6	**1**	18.31	36.62	35.18	33.35	35.49	29.47	36.89	**39.59**	**39.26**	**43.69**	36.61	43.69	29.47	4.33
	2	14.65	29.3	10.23	11.36	20.01	25.12	26.66	**34.68**	**32.86**	**31.29**	24.03	34.68	10.23	9.41
	3	9.11	18.22	8.89	13.03	**20.18**	**19.12**	16.49	16.48	**24.28**	**24.92**	17.92	24.92	8.89	5.42
	4	18.44	36.88	**44.23**	**43.46**	**51.52**	35.91	**54.93**	**48.53**	27.56	34.89	42.63	54.93	27.56	9.26
7	**1**	21.6	43.2	37.59	36.77	17.87	36.51	29.16	38.29	**61.39**	14.61	34.02	61.39	14.61	14.42
	2	13.63	27.26	17.83	**30.1**	**28.2**	25.84	12.5	24.71	16.09	16.01	17.88	30.1	12.5	9.37
8	**1**	129.92	259.84	182.67	227.86	252.79	255.1	177.87	256.82	**275.3**	214.15	230.32	275.3	177.87	36.12
9	**1**	23.27	46.54	35.8	**50.89**	**75.6**	**60.49**	43.92	35.43	**91.1**	**65.95**	57.4	91.1	35.43	19.72
	Sum	673.98	1347.96	1124.68	1089.59	1301.34	1125.33	866.63	1138.85	1333.25	1073.07				
			Average	1131.59											

Table 6.10: Mouse click count

Mouse Click Count

Scenario	Task	P0 (Pilot Study)	Alloted count	P1	P2	P3	P4	P5	P6	P7	P8	Mean	Max	Min	StDev
1	1	32	64	41	24	44	37	38	29	26	30	34	44	24	7
2	1	14	28	27	16	11	14	28	26	**36**	**32**	24	36	11	9
3	1	15	30	17	**34**	15	20	20	24	23	21	22	34	15	6
	2	19	38	19	21	18	21	18	19	19	24	20	24	18	2
	3	11	22	14	11	12	12	10	11	13	17	13	17	10	2
4	1	4	8	**10**	**24**	4	7	**9**	8	7	7	10	24	4	6
	2	2	4	1	2	2	1	4	2	2	2	2	4	1	1
	3	5	10	**14**	7	4	6	6	4	8	**11**	8	14	4	4
5	1	86	172	112	86	84	86	86	87	90	100	91	112	84	10
	2	2	4	2	2	2	2	2	2	2	2	2	2	2	0
6	1	4	8	6	4	6	5	6	4	4	7	5	7	4	1
	2	3	6	3	3	3	4	**7**	4	5	**7**	5	7	3	2
	3	3	6	2	3	3	3	4	3	3	3	3	4	2	1
	4	4	8	3	**9**	**11**	7	**15**	6	7	8	8	15	3	4
7	1	4	8	4	7	6	4	5	**9**	6	6	6	9	4	2
	2	3	6	3	**7**	3	**7**	3	5	3	5	5	7	3	2
8	1	19	38	23	24	22	30	20	**46**	23	27	27	46	20	8
9	1	7	14	12	**15**	**22**	**17**	**19**	4	**18**	13	15	22	4	6
	Sum	237	474	313	299	272	283	300	293	295	322				
			Average	297											

Table 6.11: Summary of total visit duration

Total Visit Duration						
Scenario	Task	Alloted Time	Completion Rates (%)	Observed Average Time	Best Observed Result	Worst Observed Result
1	1	162.56	100	135.19	97.89	**176.6**
2	1	103.72	100	85.98	59.82	**117.05**
3	1	77.48	100	69.29	52.58	**85.51**
	2	59.2	100	39.06	21.6	48.38
	3	47.82	100	34.43	19.56	41.82
4	1	68.46	100	68.98	35.45	**99.47**
	2	34.38	100	18.07	12.45	23.23
	3	27.32	100	**34.53**	16.06	**68.88**
5	1	249.28	100	169.48	125.87	**255.12**
	2	19.88	100	12.25	9.31	16.11
6	1	36.62	100	36.61	29.47	**43.69**
	2	29.3	100	24.03	10.23	**34.68**
	3	18.22	100	17.92	8.89	**24.92**
	4	36.88	100	**42.63**	27.56	**54.93**
7	1	43.2	100	34.02	14.61	**61.39**
	2	27.26	100	17.88	12.5	**30.1**
8	1	259.84	100	230.32	177.87	**275.3**
9	1	46.54	100	57.4	35.43	**91.1**

Table 6.12: Summary of mouse click count

Mouse Click Count						
Scenario	Task	Alloted Count	Completion Rates (%)	Observed Average Count	Best Observed Result	Worst Observed Result
1	1	64	100	34	24	44
2	1	28	100	24	11	**36**
3	1	30	100	22	15	**34**
	2	38	100	20	18	24
	3	22	100	13	10	17
4	1	8	100	10	4	**24**
	2	4	100	2	1	4
	3	10	100	8	4	**14**
5	1	172	100	91	84	112
	2	4	100	2	2	2
6	1	8	100	5	4	7
	2	6	100	5	3	**7**
	3	6	100	3	2	4
	4	8	100	8	3	**15**
7	1	8	100	6	4	**9**
	2	6	100	5	3	**7**
8	1	38	100	27	20	**46**
9	1	14	100	15	4	**22**

6.4.2. Findings and Discussions of Qualitative Data

The rate of help use of participants when conducting the tasks, are captured by the test facilitator during the session audits. The level of help use represents how easy the tool can be used by test participants without encountering with any problem or confusion. Average help use rates of participants in all tasks as well as average help use utilized by all participants for the specified scenario, are given in Table 6.13. As was given in Table 6.8, the maximum acceptable level of help use is defined as 30%. However, in scenarios 4 and scenario 9, the average help use rates of participants are exceeded the acceptable level. As will be given in the forthcoming section, the high level of help use during these scenarios can be attributed to the problems that users encounter while conducting these scenarios. Average help use rates are also calculated for each participant. Except from participant 7, the levels of overall help use of all participants are less than the acceptable level. To be noted that, the highest test completion time is belong to the participant 7. In overall, the average help use rate per participant and per scenario is calculated as 16,67%, which is less than the acceptable level.

Table 6.13: Help use rate

	Scenario									
Participant	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Help Use Rate/ Participant**
1	No	No	No	Yes	No	No	No	No	Yes	22,22%
2	No	No	No	Yes	No	No	No	No	Yes	22,22%
3	No	No	No	Yes	No	No	No	No	Yes	22,22%
4	No	No	No	No	No	No	No	No	No	0,00%
5	No	No	No	No	No	No	No	No	No	0,00%
6	No	No	No	No	No	No	No	No	No	0,00%
7	No	Yes	Yes	Yes	No	No	No	No	Yes	44,44%
8	No	No	No	Yes	No	No	No	No	Yes	22,22%
Help Use Rate/ Scenario	0,00%	12,50%	12,50%	62,50%	0,00%	0,00%	0,00%	0,00%	62,50%	**16,67%**

In addition to the record of the help use rate of participants, test facilitator identified participant problems that they encountered in conducting laboratory tests. Table 6.14 gives these problems along with the participant and scenario information. In addition, Table 6.15 gives the most critical problems encountered during the test sessions along with their frequency of occurrence. Average problem rates of participants in all tasks as well as average problems faced by all participants for the specified scenario, are given in Table 6.16. It is observed that, scenario 2, scenario 4, and scenario 9 are the critical ones in which participants were mostly encountered with some problems. However, average problem rate per participant and per scenario is estimated as 30.56 %. To be noted that, the participant who encountered with the highest level of problems is the participant 7.

Table 6.14: Identified problems through session audit

Participant	Scenario	Problem
1	1	Faced difficulty to open new project interface
1	2	Faced difficulty to open attribute setting interface
1	2	Assigned weights for wrong attribute, later found the correct attributes
1	4	Faced difficulty to open lessons learned database interface
1	4	Could not understand how to assign rating of the retrieved case to the relevant vulnerability source, he thought that rating of the retrieved case will be automatically displayed at the relevant vulnerability source.
2	2	Faced difficulty to save vulnerability source ratings, did not click on save button
2	4	Could not understand how to assign rating of the retrieved case to the relevant vulnerability source, he thought that rating of the retrieved case will be automatically displayed at the relevant vulnerability source.
3	1	At first, did not understand that the finish date of the project will be changed automatically, participant attempted to change finish date by her.
3	5	Attempted to move the cursor among the rating boxes of vulnerability sources using 'tab' key
3	9	Confused when opening the case library, participant perceived the task as 'opening a case'
4	2	Faced difficulty to open attribute setting interface
4	8	When defining case summary, participant thought that he can select vulnerability source by clicking on the whole box, later he used dropdown menu icon
5	9	Confused when opening the case library, participant perceived the task as 'opening a case'
6	1	Participant thought that she can select project information (i.e. contract type) by clicking on the whole box, later she used dropdown menu icon
6	4	Could not understand how to assign rating of the retrieved case to the relevant vulnerability source, she thought that rating of the retrieved case will be automatically displayed at the relevant vulnerability source.
6	9	Confused when opening the case library, participant perceived the task as 'opening a case'
7	2	Faced difficulty to open attribute setting interface

Table 6.14 : (Cont'd)

7	3	When defining attribute rating, he wanted to type the rating, did not want to use dropdown menu
7	4	Could not understand how to visualize rating of the retrieved case, he did not understand that he should click on the case ID to see summary of the relevant case
7	4	Could not understand how to assign rating of the retrieved case to the relevant vulnerability source, he thought that rating of the retrieved case will be automatically displayed at the relevant vulnerability source.
7	5	Attempted to move the cursor among the rating boxes of vulnerability sources using 'tab' key
7	7	Faced difficulty to open sensitivity analysis interface
7	9	Confused when opening the case library, participant perceived the task as 'opening a case'
8	3	When defining attribute rating, he wanted to type the rating, did not want to use dropdown menu
8	5	Attempted to move the cursor among the rating boxes of vulnerability sources using 'tab' key
8	9	Confused when opening the case library, participant perceived the task as 'opening a case'

Table 6.15: Most critical problems

Scenario	Most Critical Problems	Frequency
2	Faced difficulty to open attribute setting interface	4
4	Could not understand how to assign rating of the retrieved case to the relevant vulnerability source, he thought that rating of the retrieved case will be automatically displayed at the relevant vulnerability source.	3
5	Attempted to move the cursor among the rating boxes of vulnerability sources using 'tab' key	3
9	Confused when opening the case library, participants perceived the task as 'opening a case'	5
1, 6	Participants thought they can select the related information by clicking on the whole box, they could not undestand to click on the dropdown menu icon	2
3	Rather than using the dropdown menu, they wanted to type the attribute rating manually.	2
4	Could not undestand how to visualize rating of the retrieved case, they did not understant that they should click on the case ID to see summary of the relevant case	2

Table 6.16 Problem rate

Participant	Scenario 1	2	3	4	5	6	7	8	9	Problem Rate/ Participant
1	*	*	-	*	-	-	-	-	-	33.33%
2	-	*	-	*	-	-	-	-	-	22.22%
3	*	-	-	-	*	-	-	-	-	22.22%
4	-	*	-	-	-	-	-	*	-	22.22%
5	-	-	-	-	-	-	-	-	*	11.11%
6	*	-	-	*	-	-	-	-	*	33.33%
7	-	*	*	*	*	-	*	-	*	66.67%
8	-	-	*	-	*	-	-	-	*	33.33%
Problem Rate/ Scenario	37.50%	50.00%	25.00%	50.00%	37.50%	0.00%	12.50%	12.50%	50.00%	**30.56%**

Table 6.17 Summary of findings of the laboratory testing

Scenario	Task	Number of Unsatisfactory Data		Number of Help Use	Number of Problems
		Visit Duration	Click Count		
1	1	1	0	-	3
2	1	1	2	1	4
3	1	2	1	1	2
	2	0	0		
	3	0	0		
4	1	6	3	4	4
	2	0	0		
	3	4	2		
5	1	1	0	0	3
	2	0	0		
6	1	3	0	0	0
	2	3	2		
	3	4	0		
	4	5	3		
7	1	1	1	0	1
	2	2	2		
8	1	1	1	0	1
9	1	5	5	6	4

Table 6.17 gives the summary of the laboratory testing findings that are; total visit duration, mouse click count, number of help use and number of problems (error rate). Number of unsatisfactory data represents the number of participants who exceeded the time allotted and click count allotted values. It was observed that, scenario 4 and scenario 9 are the critical scenarios. The major problem about the scenario 4 is the participants' difficulty in finding the attribute default settings interface. Major problem related with the scenario 9 is that, participants could not understand whether to utilize 'open case' or 'case library'. However, these two problems are related with the scenarios representing the uncritical tool functions,

thus they do not perceived as highly significant problems that considerably influence the overall usability of the tool. In addition, it is believed that, after a single tool use session, they can become competent in opening the attribute default weight settings and case library.

6.4.3. Findings and Discussions of Visual Data

Tobii software provides some visualization tools that enable the record and visualization of the eye movements of the participants that fall within the defined area of interest (AOIs). Area of interests allows visualizing the required area that is significant in analyzing eye movements of participants falling in the specified area. In this study, major interfaces of the tool structures the area of interests of each test scenario. Recorded data within the defined area of interest can be visualized as gaze plots, heat maps, cluster, animated visualizations, or bee swarms.

In this study, eye tracks of participants are visualized as gaze plots, heat maps, and cluster. Gaze plots address gaze data from one or multiple recordings of participants and displays gaze points, fixations, and scan paths within the selected area of interest. Within these plots, each fixation is represented with a dot where length of the fixation can be understood from the length of the radius (Tobii Studio User Manual, 2008). Clusters represent the true areas of interests within the shape of polygons that displays the high concentrations of gaze data points recorded during the test (Tobii Studio User Manual, 2008). In this study, cluster and gaze plots associated with the scenario 1 is given to exemplify the visualization of these graphs. The findings of these graphs are given in Figure 6.4 and Figure 6.5. However, heat maps associated with the all scenarios are given as representation of heat maps is founded as significant to address fixation durations of participants. Figure 6.6 through Figure 6.13 represents the heat maps that are obtained from the Tobii Software.

“Heat maps are two-dimensional graphical representations of data where the values of a variable are shown as colors” (Bojko, 2009). Heat maps provide better and easy understanding of the data as they are represented in colors. According to Bojko (2009), from experience and intuitive nature of the color scale relating temperature, “yellow is warmer than green, orange is warmer than yellow, and red is hot”. Thus, the amount of heat represents the level of the related variable such as number of fixations, duration of fixations). Using a color scale, Tobii software creates heap maps based on the gaze data of multiple recordings to represent the number of or duration of fixations participants made within the certain area of interest. Fixation can be defined as a stationary eye track of participants focused on a specific location of a stimulus (Bojko, 2009). Within the heat maps, “red usually indicates the highest number of fixations or the longest time, and green the least, with varying levels in between" (Tobii Studio User Manual, 2008). In this study, heat maps are used to represent how long the participants fixated within the major interfaces of the tool. Fixation duration heat map shows the accumulated time of test participants fixating at certain areas of the interfaces. The color of the map varies in directly proportional to duration participants fixated. As the fixation of participants to a specific area gets high, the color of this area will become red. As was recommended in Bojko (2009), in this study heat maps are utilized to supplement the quantitative data by representing where the participants mostly fixated, how the participants' attention distributed as well as by indicating any inconsistencies or inefficiency of participant fixation within the certain interfaces. Fixation duration heat maps are obtained for the interfaces of; project information, attribute setting, attribute analysis, lessons learned database, risk map, sensitivity analysis, add new case and case library.

To be noted that, Tobii software creates time frame for each participant that represent the total time spent of participants in conducting the all test scenarios. While obtaining quantitative data of each test scenario, some test scenes are created within the Tobii software to capture the separate time or mouse click measures within the duration of each test scenario duration. Thus, quantitative data are recorded based on time frame of the test scenes. While obtaining quantitative data, the data within the each test scene totally represent associated test scenarios. However, in obtaining visual data this was not the case. In some scenarios, participants uses more than one interfaces to conduct the given task, thus the data within the test scene captures recordings associated with multiple scenes. On the other hand, capturing the whole data (i.e. how long the time spent in conducting the test scenarios) in a single heat map is not a reliable approach as it also consist data of other interfaces associated with the task. Thus, other test scenes were created in order to capture only the quantitative data of test scenarios that falls within a specific interface, which will further be used as heat maps. The heat maps obtained from the Tobii software reveal that, accumulated fixations of participants focused mostly around the targeted regions. That is, the regions that one should look when conducting test scenarios.

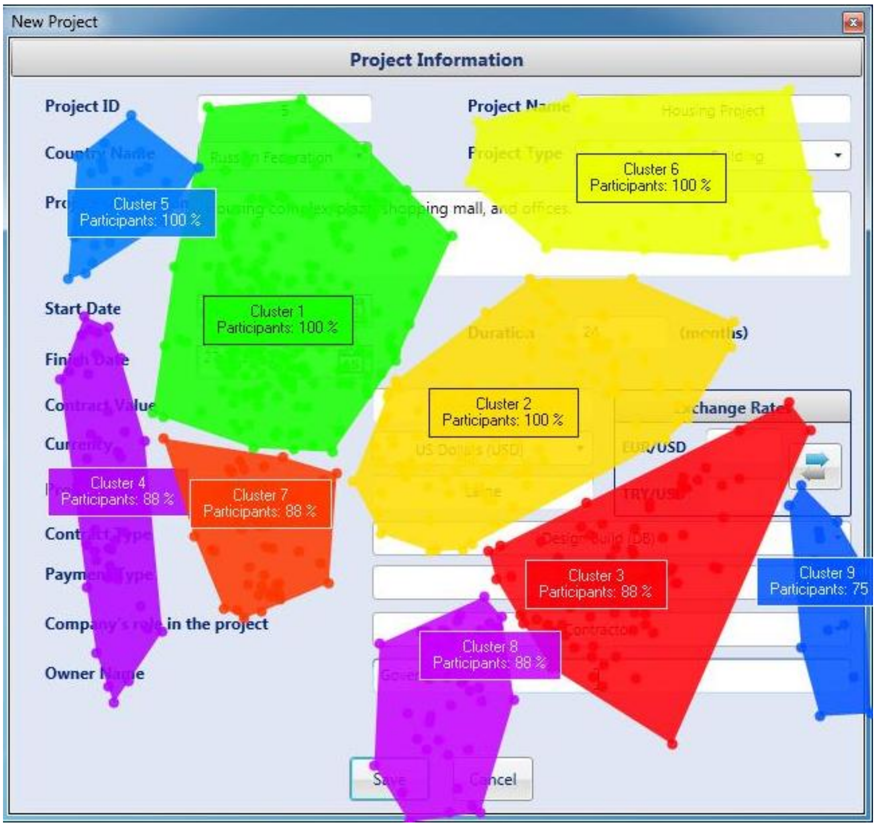

Figure 6.4: Cluster of scenario 1

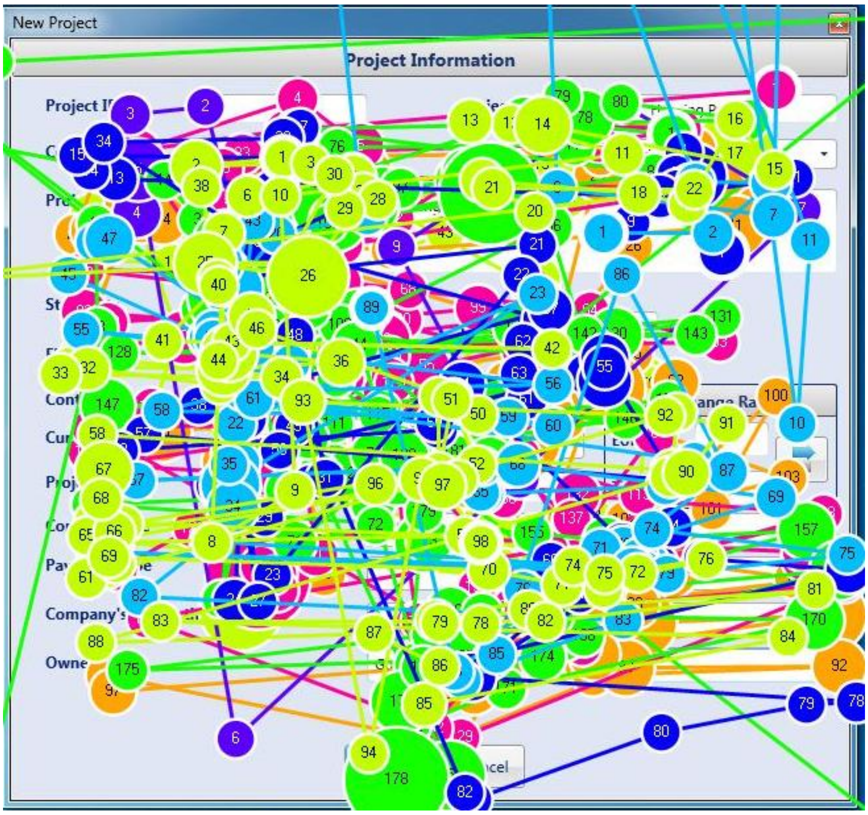

Figure 6.5: Gaze plot of scenario 1

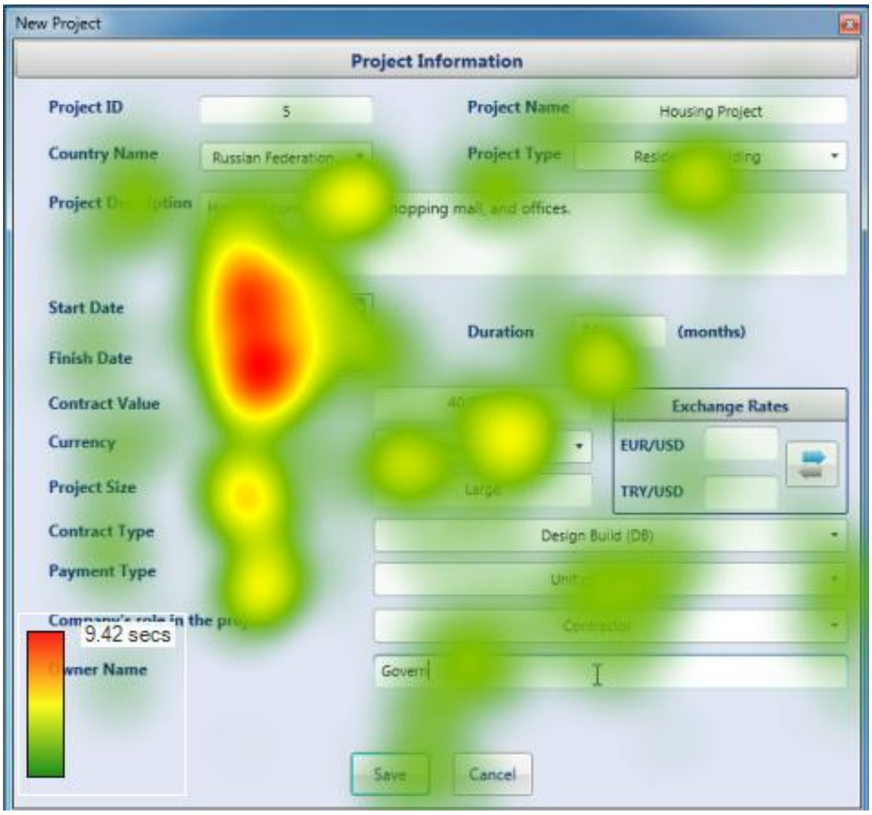

Figure 6.6: Heat map of scenario 1

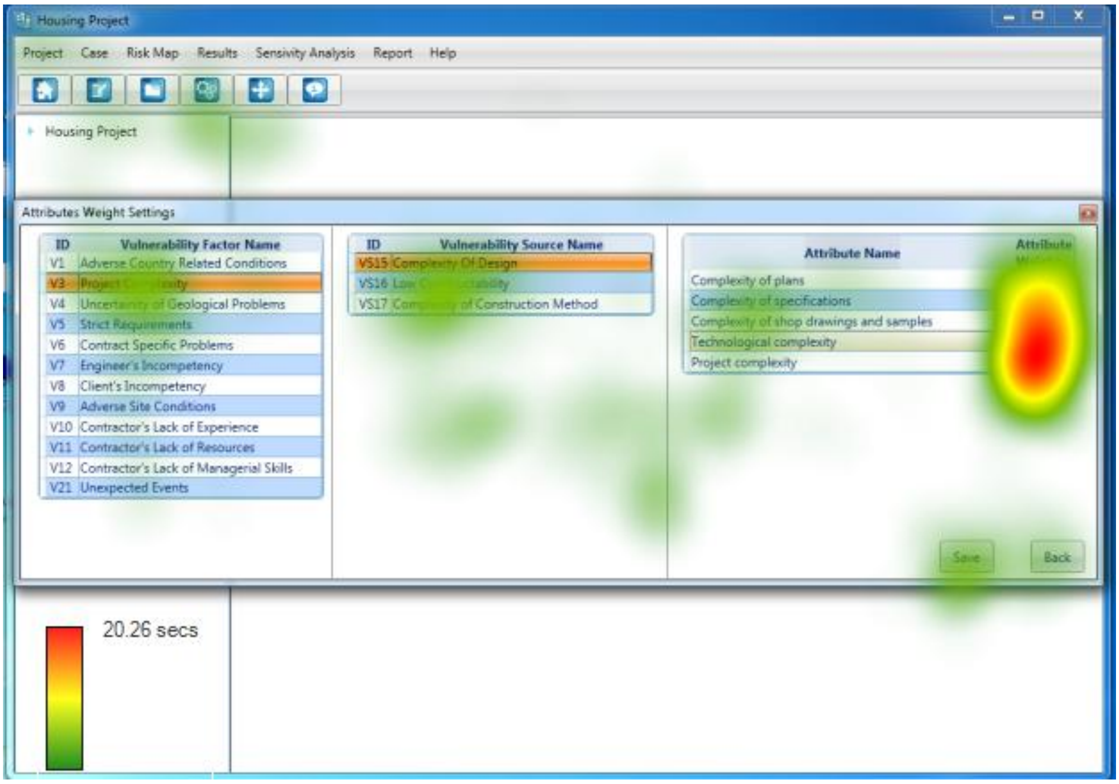

Figure 6.7: Heat map of scenario 2

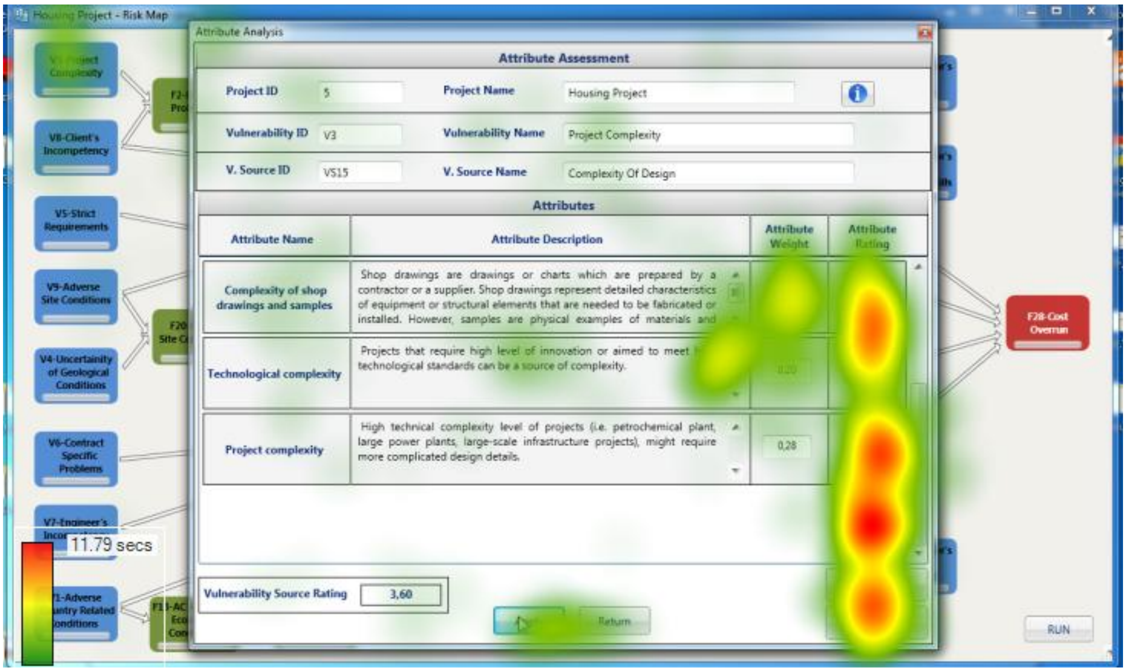

Figure 6.8: Heat map of scenario 3

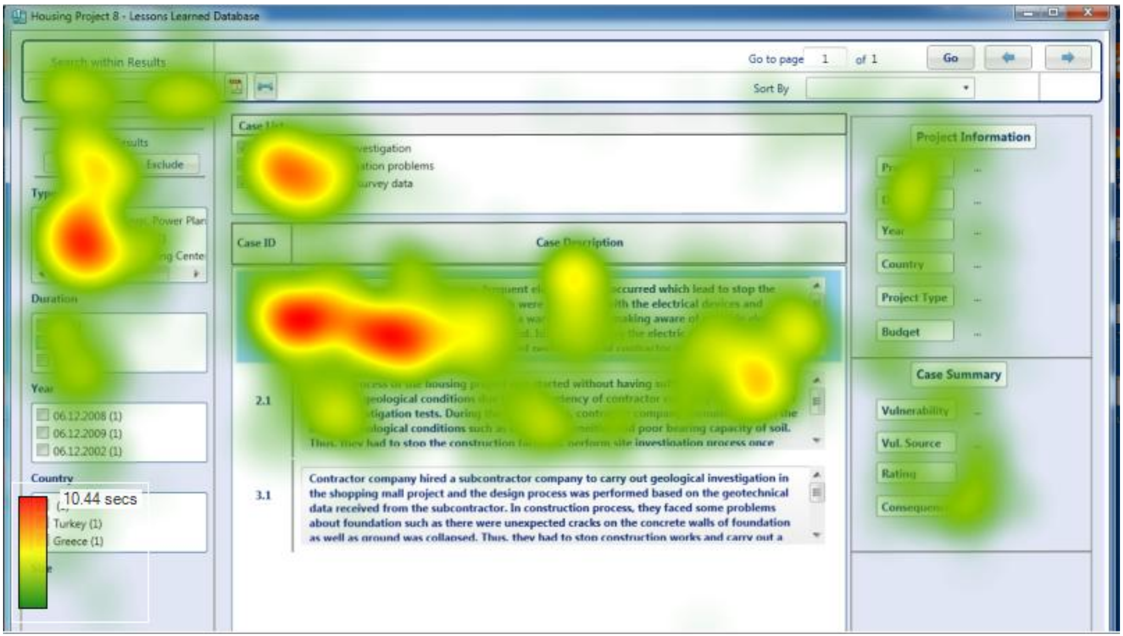

Figure 6.9: Heat map of scenario 4

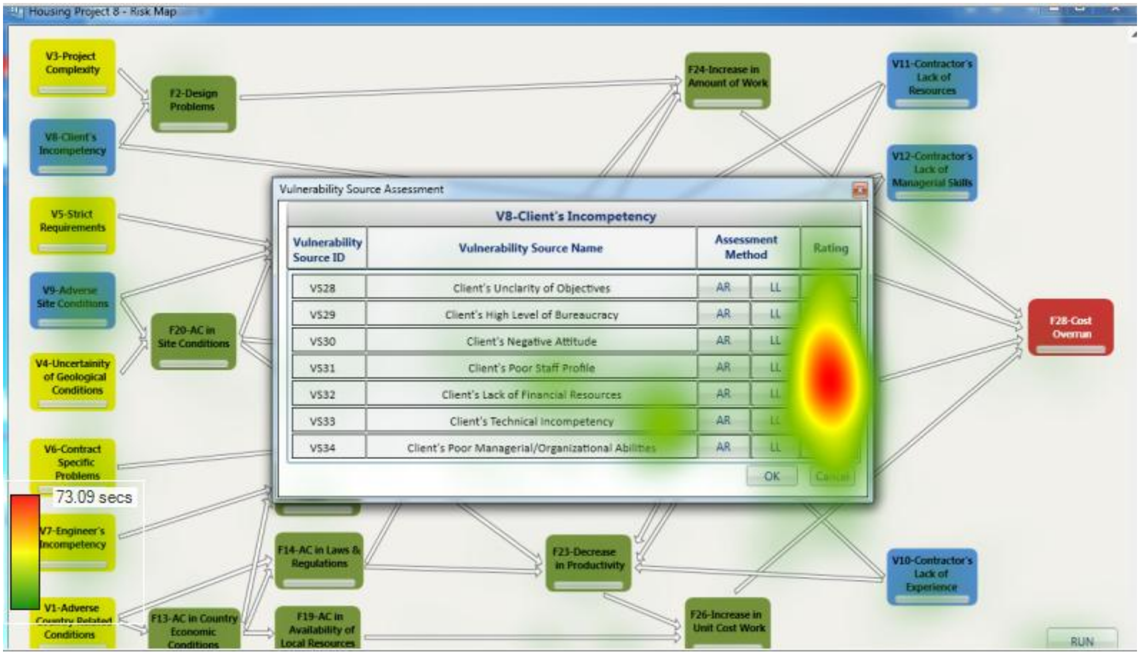

Figure 6.10: Heat map of scenario 5

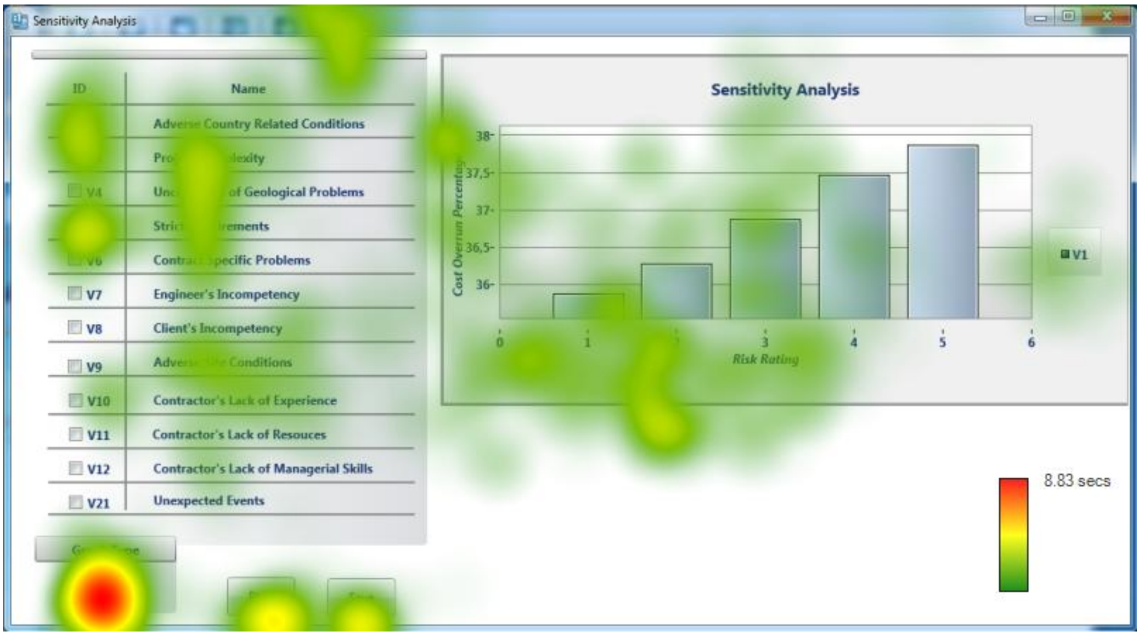

Figure 6.11: Heat map of scenario 7

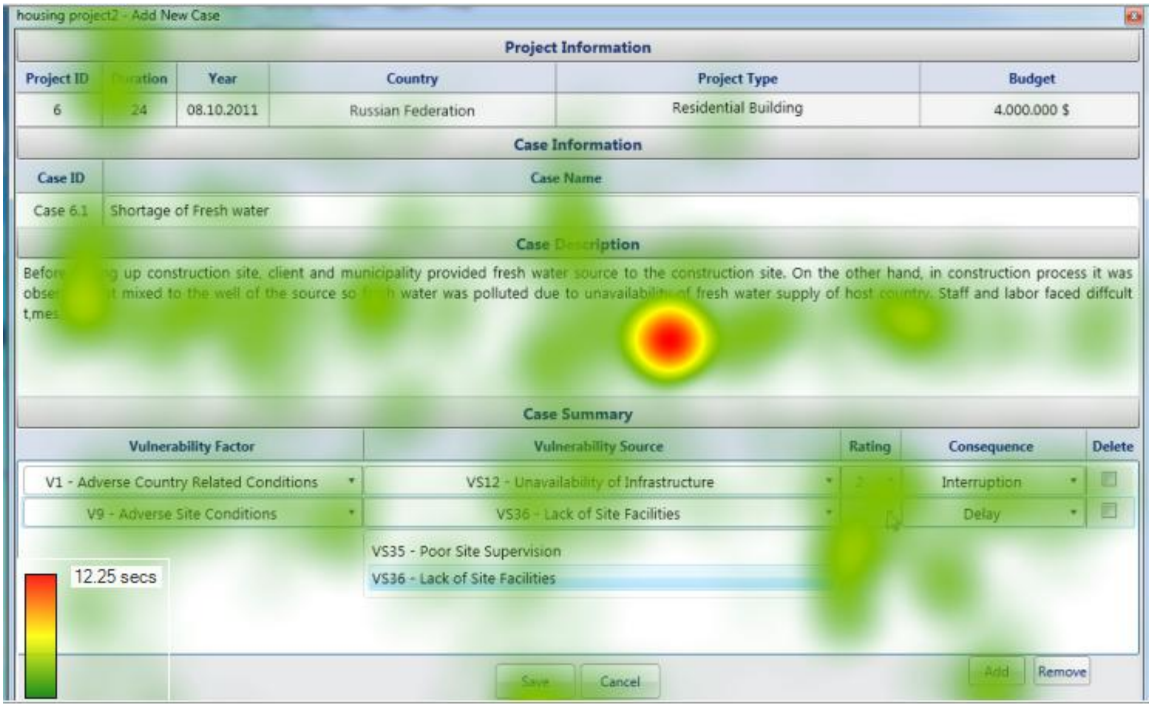

Figure 6.12 Heat map of scenario 8

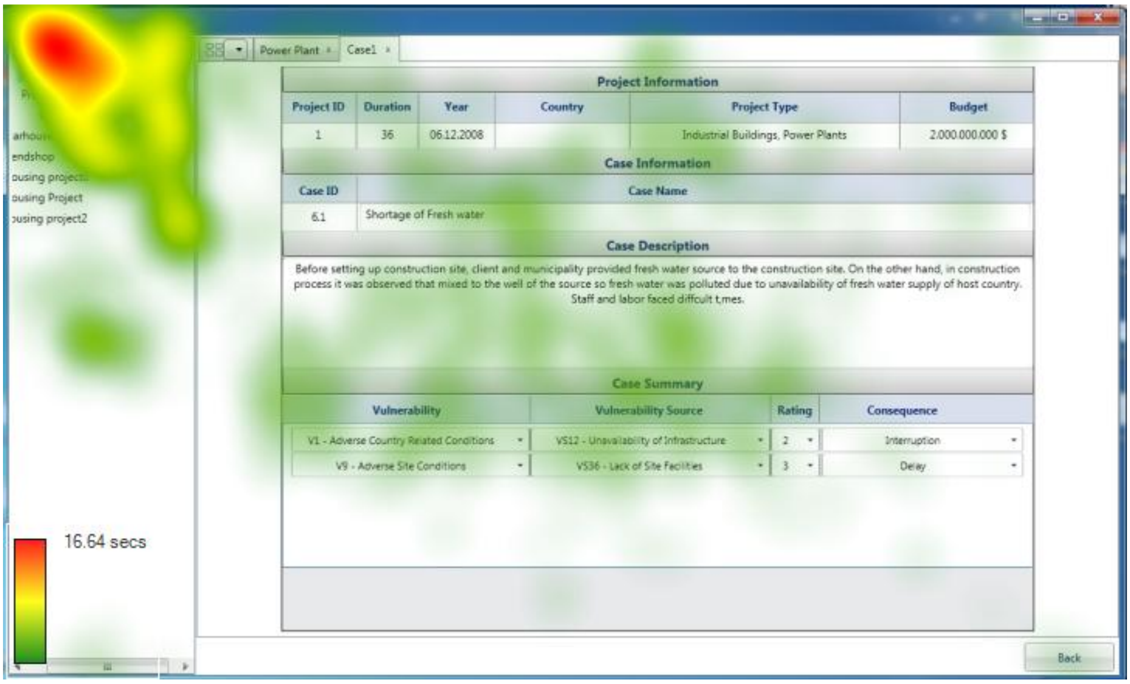

Figure 6.13: Heat map of scenario 9

6.5. Findings and Discussions of Post-Task Questionnaires

Findings of the post-task questionnaires give the understanding of the overall usability attributes of the tool. The detailed responses of each test participant on the usability attributes of the associated test scenarios are given in Table 6.18 through

Table 6.26. In addition, Table 6.27 summarizes the responses of participants captured through post-task questionnaires. When conducting the first test scenario (assigning project information), the most critical attribute is the learnability of assigning a new project into the tool. Participants though that, they could not easily learn how to assign a new project into the tool. The ratings of the each usability attribute as well as the overall scenario usability are higher than the usability benchmark assigned to the post-task questionnaires, that is 4 from 1-5 rating scale. The responses on the second scenario of the participants reveal the test session problems that are recorded in session audits by test facilitator. Participants P1, P4 and P7 are moderately agree in the ease of finding the attribute settings interface. To be highlighted that; test facilitator also observed in test sessions that, these participants faced difficulty in opening the attribute settings interface. In addition, other critical issues regarding this scenario is the, participants slightly think that they are not familiar with the terminology of the attribute settings interface as well as they found finding the relevant attributes as difficult. The most critical usability attribute of this scenario is 'learnability'. Similar to the scenario 1, participants slightly agree that learning how to conduct the scenario is easy. However, the rating of the each usability attribute as well as the overall usability of the scenario is satisfactory. The major problem regarding the third scenario is the unfamiliarity with the terminology used in the attribute analysis interface. The most critical usability attribute is the ease of using the attribute analysis function of the risk mapping tool. Ratings of all attributes as well as overall usability level of the attribute analysis function are found as satisfactory. The responses of the post-task questionnaires represented that the most critical scenario of the test is the use of lessons learned database interface. Participant responses on post-task questionnaire of lessons learned database showed that, the most critical usability attributes of this function are the 'ease of use', 'satisfaction' and 'learnability'. Participants thought that they could not carried out task easily, and the terminology of the interface is unfamiliar to them. However, usability attributes of the fourth scenario are still equal or higher than the usability benchmark. The overall usability level of using lessons learned database is 4.29, which reveals the success of this function despite some minor problems. Participant responses demonstrated that there are not any major problem in conducting scenario5, scenario 6, scenario 7, and scenario 8. Overall usability level of conducting these scenarios as well as levels of each usability attribute is perceived as satisfactory by the test participants. Finally, the major problem regarding the final scenario is

the difficulty of opening case library interface by test participants. The perception of participants on finding the case library revealed the findings of the test session audits. The test facilitator also observed that, some participants faced difficult to understand what they should do and how they can open the case library interface. However, ratings of usability attributes as well as their average ratings are higher than the defined benchmark. Thus, conducting the final scenario by test participants also perceived as satisfactory. In addition, the results of the usability test revealed that, the proposed help menu of the risk mapping tool is helpful for the selected practitioners when using the features of the tool as well as conducting risk assessment process.

Table 6.18: Questionnaire responses of scenario 1

Tool Function 1 (Scenario 1- Assigning a new project)												
Usability Attribute	**Question**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**Question Average**	**Attribute Average**	**Task Average**
Ease of Use	It is easy to find how to open the interface.	**3**	5	5	5	5	5	4	5	4.63	4.56	4.45
	The automatic functions (i.e. estimation of finish date automatically, determination of project size) help me be more productive.	4	5	5	4	5	5	4	4	4.50		
	The project information given in this interface is clear.	**3**	5	5	4	5	5	4	5	4.50		
	The terminology used is clear and understandable.	**3**	5	4	5	4	5	5	4	4.38		
	It is easy to find and use buttons.	4	5	5	4	5	5	**3**	5	4.50		
	It is easy to assign a project into the tool.	5	5	5	5	5	5	4	5	4.88		
Satisfaction	It works the way I expected.	4	5	5	4	5	4	4	4	4.38	4.38	
	The amount of project information included is sufficient.	4	4	5	5	5	4	4	4	4.38		
Consistency	The project information provided is relevant with the task.	**3**	5	5	5	5	5	4	4	4.50	4.41	
	The ordering of project information is logical.	4	5	5	5	4	5	**3**	5	4.50		
	The interface is well suited.	**3**	5	5	5	5	4	4	5	4.50		
	I do not observe any inconsistencies when I use it.	**2**	4	5	5	5	5	**3**	4	4.13		
Learnability	I learned to perform task quickly.	4	5	5	**3**	4	**3**	**3**	5	**4.00**	4.23	
	I easily remember how to carry out this task.	4	4	5	4	5	4	4	4	4.25		
	It is easy to remember the interface.	4	5	5	4	5	4	4	4	4.38		
	I can perform this task successfully every time.	4	5	5	4	4	5	**3**	5	4.38		
	I can perform this task without help.	**3**	4	5	4	4	4	4	5	4.13		
User Guidance	Information messages are helpful.	4	5	5	4	5	4	4	4	4.38	4.69	
	It provides cancel or return options.	5	5	5	5	5	5	5	5	5.00		
	The help option is useful. (applicable, if help is used)	-	-	-	-	-	-	-	-	-	-	

Table 6.19: Questionnaire responses of scenario 2

Tool Function 2 (Scenario 2- Defining default attribute weights)													
Usability Attribute	**Question**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**Question Average**	**Attribute Average**	**Task Average**
Ease of Use	It is easy to find how to open attribute settings interface.	**3**	5	5	4	5	5	**3**	5	4.38	4.33	4.44
	The terminology used is familiar to me.	**2**	4	4	4	4	4	4	4	**3.75**		
	The terminology used is clear and understandable.	**3**	4	4	4	4	5	4	5	4.13		
	It is easy to find required attributes.	**2**	5	5	4	4	5	4	**3**	**4.00**		
	It is easy to find and use buttons.	**3**	5	5	5	5	5	4	4	4.50		
	It is easy to assign default weights.	4	5	5	5	5	5	4	5	4.75		
	Overall, it is easy to assign default weights.	4	5	5	5	5	5	4	4	4.63		
	Overall, the interface is clear and usable.	**3**	5	5	5	5	5	4	4	4.50		
Satisfaction	It is useful to assign default weights and use it.	4	4	5	4	5	5	4	**3**	4.25	4.38	
	It works the way I expected.	**3**	4	5	5	5	5	4	5	4.50		
Consistency	The given attributes are relevant with the task.	4	5	5	5	5	4	5	5	4.75	4.50	
	The ordering of vulnerability-vulnerability source-attribute is logical.	4	4	5	5	5	4	4	4	4.38		
	The interface is well suited.	**3**	5	5	5	5	5	4	5	4.63		
	I do not observe any inconsistencies when I use it.	**1**	5	5	5	5	5	**3**	5	4.25		
Learnability	I learned to perform task quickly.	**3**	4	5	4	5	4	4	4	4.13	4.31	
	I easily remember how to carry out this task.	**3**	4	5	4	5	5	4	4	4.25		
	It is easy to remember the interface.	**3**	5	5	4	5	5	4	5	4.50		
	I can perform this task successfully every time.	**3**	5	5	4	5	5	**3**	4	4.25		
	I can perform this task without help.	**2**	4	5	4	5	5	4	4	4.13		
	The representation of attributes makes it easy to understand.	4	5	4	5	5	5	5	4	4.63		
User Guidance	Information messages are helpful.	**3**	4	5	5	5	4	**3**	4	4.13	4.67	
	It provides normalization of attribute weights.	5	5	5	5	5	5	4	5	4.88		
	The help option is useful. (applicable, if help is used)	-	-	-	-	-	-	5	-	5.00		

Table 6.20: Questionnaire responses of scenario 3

Tool Function 3 (Scenario 3- Using attributes in risk assessment process)													
Usability Attribute	**Question**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**Question Average**	**Attribute Average**	**Task Average**
Ease of Use	It is easy to find how to open attribute analysis interface.	4	4	3	4	5	5	3	5	4.13	4.48	4.64
	The given information is clear.	5	5	5	3	5	5	4	4	4.50		
	The automatic functions (i.e. display of project information, risk variable information) help me be more productive.	5	5	5	4	5	5	5	4	4.75		
	The terminology used is familiar to me.	2	4	4	5	4	3	5	5	4.00		
	The terminology used is clear and understandable.	4	4	4	5	5	4	4	4	4.25		
	It is easy to find required attributes.	1	5	5	5	5	5	4	5	4.38		
	It is easy to find and use buttons.	3	4	5	4	5	5	3	5	4.25		
	It easy to assign attribute rating.	3	5	5	4	5	5	4	5	4.50		
	It is useful to assign default weights.	4	5	5	4	5	5	5	5	4.75		
	It useful to utilizing “use equal weight” button.	5	5	5	5	5	5	4	5	4.88		
	The automatic calculation of vulnerability source rating is useful.	5	5	5	5	5	5	3	4	4.63		
	Overall, it is easy to do this task.	4	5	5	4	5	5	4	4	4.50		
	Overall, the interface is clear and usable.	4	5	5	5	5	5	5	4	4.75		
Satisfaction	I am satisfied with the task.	5	4	5	4	5	5	3	4	4.38	4.71	
	The amount of information included is sufficient.	5	5	5	5	5	4	5	5	4.88		
	It works the way I expected.	5	5	5	5	5	5	5	4	4.88		
Consistency	The information provided is relevant with the task.	5	5	5	5	5	5	4	4	4.75	4.72	
	The ordering of project information is logical.	5	5	5	5	5	5	3	5	4.75		
	The interface is well-suited and consistent with other interfaces.	4	5	5	5	5	5	4	5	4.75		
	I do not observe any inconsistencies when I use it.	5	4	5	5	5	5	4	4	4.63		
Learnability	I learned to perform task quickly.	4	4	5	4	5	4	4	5	4.38	4.50	
	I easily remember how to carry out this task.	5	5	5	4	5	5	4	4	4.63		
	It is easy to remember the interface.	5	5	5	4	5	4	5	4	4.63		
	I can perform this task successfully every time.	5	5	5	4	5	5	3	4	4.50		
	I can perform this task without help.	5	4	5	4	5	4	4	3	4.25		
	The representation of attributes (i.e.order, font) makes it easy to understand.	4	5	5	5	5	5	4	4	4.63		
User Guidance	Information messages are helpful.	5	5	5	5	5	4	5	4	4.75	4.81	
	It provides normalization of attribute weights.	5	5	5	5	5	5	4	5	4.88		
	The help option is useful. (applicable, if help is used)	-	-	-	-	-	-	3	-	-		

Table 6.21: Questionnaire responses of scenario 4

Tool Function 4 (Scenario 4- Using lessons learned database												
Usability Attribute	**Question**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**Question Average**	**Attribute Average**	**Task Average**
Ease of Use	It is easy to find how to open lessons learned database interface.	**1**	**3**	**3**	4	**2**	4	4	4	**3.13**	**4.02**	4.29
	The given information is clear.	**1**	4	4	4	4	**3**	**3**	4	**3.38**		
	The terminology used is familiar to me.	**1**	**3**	4	5	4	**3**	**3**	4	**3.38**		
	The terminology used is clear and understandable	**1**	5	4	5	**3**	5	4	**3**	**3.75**		
	The word searching is easy.	5	5	5	4	5	5	4	4	4.63		
	The word searching is useful.	5	5	5	4	5	5	4	5	4.75		
	The results refining is easy.	**3**	5	4	4	5	5	**3**	5	4.25		
	The results refining is useful.	**3**	5	5	4	5	5	**3**	5	4.38		
	The automatic functions (i.e. display of case summary) help me be more productive.	5	4	5	4	5	5	5	4	4.63		
	It is easy to find and use buttons.	**3**	5	4	**3**	5	5	4	4	4.13		
	Overall, it is easy to do this task.	**2**	**3**	**3**	4	**3**	4	4	4	**3.38**		
	Overall, the interface is clear and usable.	**3**	5	5	4	5	5	5	4	4.50		
Satisfaction	I am satisfied with the interface.	**1**	4	5	4	5	5	**3**	**3**	**3.75**	**4.00**	
	The amount of information included is sufficient.	**3**	4	5	4	5	4	4	4	4.13		
	It works the way I expected.	**3**	5	5	4	5	4	**3**	4	4.13		
Consistency	The information provided is relevant with the task.	5	5	5	4	5	5	5	5	4.88	4.69	
	The ordering of information is logical.	5	5	5	4	5	5	5	5	4.88		
	The interface is well-suited and consistent with other interfaces.	**3**	5	5	5	4	4	4	5	4.38		
	I do not observe any inconsistencies when I use it.	**3**	5	5	5	5	5	4	5	4.63		
Learnability	I learned to perform task quickly.	**2**	**3**	**3**	4	**3**	4	5	4	3.50	**4.04**	
	I easily remember how to carry out this task.	**2**	4	4	4	**3**	4	5	4	3.75		
	It is easy to remember the interface.	**2**	5	5	4	5	5	4	4	4.25		
	I can perform this task successfully every time.	**2**	5	5	4	5	5	**3**	**3**	**4.00**		
	I can perform this task without help.	**1**	5	5	4	5	5	5	4	4.25		
	The representation of case sumary makes it easy to understand.	**3**	5	5	5	5	5	4	4	4.50		
User Guidance	Information messages are helpful.	4	5	5	5	5	5	4	5	4.75	4.68	
	The help option is useful. (applicable, if help is used)	4	5	5	-	-	-	4	5	4.60		

Table 6.22: Questionnaire responses of scenario 5

Tool Function 5 (Scenario 5- Carrying out risk assessment)												
Usability Attribute	**Question**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**Question Average**	**Attribute Average**	**Task Average**
Ease of Use	It is easy to find how to open risk map interface.	5	5	5	5	5	5	4	5	4.88	4.69	4.63
	The given information is clear.	5	5	5	4	5	5	4	4	4.63		
	The terminology used is familiar to me.	5	5	5	4	5	4	4	4	4.50		
	The terminology used is clear and understandable..	5	4	5	5	5	5	5	3	4.63		
	The representation of risk variables on the risk map is useful. (i.e. color, shape)	5	4	5	5	5	5	4	4	4.63		
	The representation of risk paths on the risk map is useful. (i.e. color, shape)	5	5	5	5	5	5	4	5	4.88		
	It easy to find how to assign ratings of risk variables.	5	5	5	5	5	5	5	5	5.00		
	It is easy to find and use buttons.	5	5	5	**3**	5	5	**3**	5	4.50		
	It is easy to follow which vulnerabilities are assigned.	5	5	5	4	5	4	4	4	4.50		
	The representation of vulnerability sources is useful. (i.e. order)	5	5	5	4	5	5	4	4	4.63		
	Overall, it is easy to do this task.	5	5	5	4	5	5	5	4	4.75		
	Overall, the interface is clear and usable.	5	5	5	4	5	5	5	4	4.75		
Satisfaction	I am satisfied with the interface.	5	5	5	4	5	5	4	**3**	4.50	4.56	
	It works the way I expected.	5	5	5	4	5	5	4	4	4.63		
Consistency	The interface is well-suited and consistent with other interfaces.	5	5	5	4	5	5	**3**	4	4.50	4.69	
	I do not observe any inconsistencies when I use it.	5	5	5	4	5	5	5	5	4.88		
Learnability	I learned to perform task quickly.		5	5	4	5	4	4	5	4.57	4.56	
	I easily remember how to carry out this task.	5	5	4	4	5	4	4	5	4.50		
	It is easy to remember the interface.	5	5	4	4	5	5	**3**	5	4.50		
	I can perform this task successfully every time.	5	5	5	4	5	4	4	4	4.50		
	I can perform this task without help.	5	5	5	4	5	5	5	4	4.75		
User Guidance	Information messages are helpful.	5	5	5	4	5	5	4	**3**	4.50	4.63	
	It provides cancel or return options.	5	4	5	5	5	5	4	5	4.75		
	The help option is useful. (applicable, if help is used)	-	-	-	-	-	-	-	-	-	-	

Table 6.23: Questionnaire responses of scenario 6

Tool Function 6 (Scenario 6- evaluation and reporting results												
Usability Attribute	**Question**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**Question Average**	**Attribute Average**	**Task Average**
	It is easy to find how to open the interface.	5	5	4	4	5	5	4	5	4.63		
	The given information is clear.	4	5	5	5	5	5	4	4	4.63		
	The terminology used is familiar to me.	5	4	4	4	5	5	**3**	4	4.25		
	The terminology used is clear and understandable.	5	5	4	4	5	5	4	**3**	4.38		
	It is easy to find and use buttons.	5	5	5	4	4	5	**3**	4	4.38		
Ease of Use	It is easy to examine risk path impacts of the given paths ID.	4	5	5	**3**	4	5	4	5	4.38	4.47	
	It is easy to examine risk ratings.	4	5	5	**3**	4	5	**3**	5	4.25		
	It is easy to examine cost overrun percentage of the project.	5	5	5	**3**	4	5	5	5	4.63		
	Overall, the interface is clear and usable.	5	5	5	4	4	5	4	4	4.50		
	It is useful to document results with report information.	5	4	5	4	5	5	**3**	4	4.38		
	The ordering of report information is logical.	5	5	5	5	5	4	5	4	4.75		
	It is useful to examine critical risk paths from the cost overrun interface.	5	5	4	**2**	5	5	4	4	4.25		
Satisfaction	The amount of information included is sufficient.	5	5	5	4	5	5	**3**	**3**	4.38	4.41	
	It works the way I expected.	5	5	5	4	5	**3**	4	4	4.38		4.58
	It is useful to document the results.	5	5	5	4	5	5	4	4	4.63		
	The information provided is relevant with the task.	5	5	5	5	5	5	5	5	5.00		
	The ordering of risk-related variables is consistent with the risk map.	5	4	5	4	5	5	5	5	4.75		
Consistency	The interface is well-suited and consistent with other interfaces.	5	5	5	4	5	5	5	5	4.88	4.78	
	I do not observe any inconsistencies when I use it.	5	4	5	4	5	5	4	5	4.63		
	The project Id and name given in cost overrun percentage interface is consistent with the actual project information.	5	5	5	4	5	5	4	4	4.63		
	I learned to perform task quickly.	5	5	5	**3**	4	5	**3**	4	4.25		
	I easily remember how to carry out this task.	5	4	5	**3**	5	5	4	4	4.38		
Learnability	It is easy to remember the interface.	5	5	4	4	5	5	5	4	4.63	4.50	
	I can perform this task successfully every time.	5	5	4	4	5	5	5	5	4.75		
	I can perform this task without help.	5	4	5	**3**	5	5	4	5	4.50		
User Guidance	Information messages are helpful.	5	5	5	4	5	5	4	5	4.75	4.75	
	The help option is useful. (applicable, if help is used)	-	-	-	-	-	-	-	-	-	-	

Table 6.24: Questionnaire responses of scenario 7

Tool Function 7 (Scenario 7- Carrying out sensitivity analysis													
Usability Attribute	**Question**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**Question Average**	**Attribute Average**	**Task Average**
Ease of Use	It is easy to find how to open sensitivity analysis interface.	5	5	5	5	5	5	4	5	4.88	4.74	4.74
	It is easy to find and to select vulnerability sources	5	5	4	5	5	5	4	4	4.63		
	The given sensitivity analysis graph is is useful.	5	5	5	5	5	5	**3**	4	4.63		
	It is easy to select graph type.	5	5	5	5	5	5	4	**3**	4.63		
	The given information is clear.	5	5	5	5	5	5	4	4	4.75		
	The terminology used is familiar to me.	5	5	4	5	5	4	**3**	5	4.50		
	The terminology used is clear and understandable.	5	5	4	5	5	5	4	5	4.75		
	It is easy to find and use buttons.	5	5	5	5	5	5	4	5	4.88		
	Overall, it is easy to do this task.	5	5	5	5	5	5	5	5	5.00		
	Overall, the interface is clear and usable.	5	5	5	5	5	5	4	4	4.75		
Satisfaction	It is useful to carry out sensitivity analysis.	5	5	5	5	5	5	4	4	4.75	4.67	
	The amount of information included is sufficient.	5	5	5	4	5	5	4	4	4.63		
	It works the way I expected.	5	5	5	5	5	4	**3**	5	4.63		
Consistency	The information provided is relevant with the task.	5	5	5	5	5	5	**3**	4	4.63	4.72	
	The ordering of vulnerabilities is consistent with the riskmap.	5	5	5	5	5	5	4	**3**	4.63		
	The interface is well-suited and consistent with other interfaces.	5	5	5	4	5	5	5	4	4.75		
	I do not observe any inconsistencies when I use it.	5	5	5	5	5	5	5	4	4.88		
Learnability	I learned to perform task quickly.	5	5	5	5	5	4	4	5	4.75	4.85	
	I easily remember how to carry out this task.	5	5	5	5	5	5	4	5	4.88		
	It is easy to remember the interface.	5	5	5	4	5	5	5	5	4.88		
	I can perform this task successfully every time.	5	5	5	5	5	5	5	5	5.00		
	I can perform this task without help.	5	5	5	5	5	5	4	4	4.75		
User Guidance	Information messages are helpful.	5	5	5	4	5	5	4	5	4.75	4.75	
	It provides cancel or return options.	5	5	5	5	5	5	4	4	4.75		
	The help option is useful. (applicable, if help is used)	-	-	-	-	-	-	-	-	-	-	

Table 6.25: Questionnaire responses of scenario 8

Tool Function 8 (Scenario 8- Adding a new case)												
Usability Attribute	**Question**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**Question Average**	**Attribute Average**	**Task Average**
Ease of Use	It is easy to find how to open the interface.	5	5	5	4	4	4	4	5	4.50	4.58	4.72
	The given information is clear.	5	5	5	4	5	5	4	4	4.63		
	The automatic functions are effective and usable. (i.e. display of project information)	4	5	5	4	5	5	5	4	4.63		
	The terminology used is familiar to me.	4	5	4	5	5	4	5	4	4.50		
	The terminology used is clear and understandable.	4	4	4	4	5	5	5	**3**	4.25		
	It is easy to find and use buttons.	5	5	4	4	5	5	4	4	4.50		
	Overall, it is easy to add a new case.	5	5	5	4	5	5	4	5	4.75		
	Overall, the interface is clear and usable.	5	5	5	4	5	5	5	5	4.88		
Satisfaction	It is useful to store past project knowledge.	5	5	5	5	5	5	5	5	5.00	4.78	
	The amount of information included is sufficient.	5	5	5	5		4	5	4	4.71		
	It works the way I expected.	5	5	5	4	5	5	4	4	4.63		
Consistency	The information provided is relevant with the task.	5	5	5	4	5	5	4	5	4.75	4.70	
	The ordering of information is logical.	5	5	5	4	5	5	5	4	4.75		
	The interface is well-suited and consistent with other interfaces.	5	5	5	4	5	5	5	**3**	4.63		
	I do not observe any inconsistencies when I use it.	5	4	5	4	5	5	5	4	4.63		
	The project Id and name given in the interface is consistent with the actual project information.	5	5	5	5	5	5	4	4	4.75		
Learnability	I learned to perform task quickly.	5	4	5	4	5	4	4	5	4.50	4.65	
	I easily remember how to carry out this task.	5	4	5	4	5	5	4	5	4.63		
	It is easy to remember the interface.	5	5	5	4	5	5	5	4	4.75		
	I can perform this task successfully every time.	5	4	5	4	5	4	5	4	4.50		
	I can perform this task without help.	5	5	5	4	5	5	5	5	4.88		
User Guidance	Information messages are helpful.	5	5	5	5	5	5	4	5	4.88	4.88	
	It provides cancel or return options.	5	5	5	5	5	5	4	5	4.88		
	The help option is useful. (applicable, if help is used)	-	-	-	-	-	-	-	-	-	-	

Table 6.26: Questionnaire responses of scenario 9

Tool Function 9 (Scenario 9- Using case library)												
Usability Attribute	**Question**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**Question Average**	**Attribute Average**	**Task Average**
Ease of Use	It is easy to find how to open case library interface.	5	5	4	5	3	3	3	3	**3.88**	4.53	4.70
	The automatic functions are effective and usable. (i.e. display of project information)	5	5	5	5	5	5	4	4	4.75		
	The given information is clear.	5	5	5	5	5	5	4	4	4.75		
	The terminology used is familiar to me.	5	5	4	5	5	4	5	4	4.63		
	The terminology used is clear and understandable.	5	5	4	4	5	5	**3**	**3**	4.25		
	It is easy to find and use buttons.	5	5	5	4	4	5	4	5	4.63		
	Overall, it is easy to do this task.	5	4	5	4	5	5	4	4	4.50		
	Overall, the interface is clear and usable.	5	5	5	5	5	5	5	4	4.88		
Satisfaction	I am satisfied with the interface.	5	5	5	4	5	5	4	4	4.63	4.81	
	The amount of information included is sufficient.	5	5	5	4	5	5	4	5	4.75		
	It works the way I expected.	5	5	5	5	5	5	5	5	5.00		
	It is useful to examine past projects and their cases.	5	5	5	5	5	5	4	5	4.88		
Consistency	The project information provided is relevant with the task.	5	5	5	4	5	5	4	4	4.63	4.59	
	The ordering of project-case information is logical.	5	5	5	4	5	5	**3**	4	4.50		
	The interface is well-suited and consistent with other interfaces.	5	4	5	4	5	5	4	**3**	4.38		
	I do not observe any inconsistencies when I use it.	5	5	5	5	5	5	5	4	4.88		
Learnability	I learned to perform task quickly.	5	4	5	5	5	5	4	5	4.75	4.68	
	I easily remember how to carry out this task.	5	4	5	4	5	5	4	5	4.63		
	It is easy to remember the interface.	5	5	5	5	5	5	**3**	4	4.63		
	I can perform this task successfully every time.	5	5	5	4	5	5	4	4	4.63		
	I can perform this task without help.	5	5	5	4	5	5	4	5	4.75		
User Guidance	Information messages are helpful.	5	5	5	5	5	5	5	4	4.88	4.88	
	It provides cancel or return options.	5	5	5	5	5	5	5	5	5.00		
	The help option is useful. (applicable, if help is used)	-	4	5	-	-	-	5	5	4.75		

Table 6.27: The summary of post-task questionnaires

Scenario/ Attribute	Ease of Use	Satisfaction	Consistency	Learnabilty	User Guidance	Scenario Overall
Scenario 1	4.56	4.38	4.41	4.28	4.69	4.45
Scenario 2	4.33	4.38	4.5	4.31	4.67	4.44
Scenario 3	4.48	4.71	4.72	4.5	4.81	4.64
Scenario 4	4.02	4	4.69	4.04	4.68	4.29
Scenario 5	4.69	4.56	4.69	4.56	4.63	4.63
Scenario 6	4.47	4.41	4.78	4.5	4.75	4.58
Scenario 7	4.74	4.67	4.72	4.85	4.75	4.74
Scenario 8	4.58	4.78	4.7	4.65	4.88	4.72
Scenario 9	4.53	4.81	4.59	4.68	4.89	4.70
Attribute Overall	4.49	4.52	4.64	4.49	4.75	**4.58**

6.6. Findings and Discussions of Post-Test Questionnaires

The participants are agreed upon the easiness of using the risk mapping tool and usability of its interfaces. Three participants responded that the most liked issue about the tool is, carrying out sensitivity analysis automatically. Authors responses are as follows; most of them think that, design of interfaces are aesthetically pleasing, risk mapping interface is easy to use, the tool serves multiple functions, automatic functions of it are useful. The least liked issues are; they thought keyboard shortcuts (i.e. tab) are insufficient, data entering is sometimes difficult and abbreviations such as ‘LL’ are confusing. Another participant responded that, although tool carries out risk assessment, risk response facilities should also be incorporated. Three participants responded that they are ‘extremely satisfied’ with their tool experience, and five participants preferred to rate it with ‘very satisfied’. Finally, it was asked to the participants whether they would use the tool if the tool were available in market. Two participants responded ‘extremely likely’, three participants responded ‘very likely’, one of them responded as ‘moderately likely’ and two of them responded as ‘slightly likely’.

CHAPTER 7

APPLICATION OF THE TOOL IN A REAL CONSTRUCTION PROJECT

This chapter introduces the application of the knowledge-based risk mapping tool in a real construction project. Firstly, the company with which the tool is applied is overviewed. In the second section, the characteristic of the project facilitated in the case study process is given. In the third section, methodology used in the case study approach is explained. In the fourth section, evaluation of the vulnerability source attributes of the case study by the company expert, is explained. Fifth section exemplifies the discussions of company expert on the retrieved project case from the lessons learned database. Finally, findings and dicussions of the case study, is given.

7.1. Overview of the Company

The proposed risk mapping tool has been applied with one of the leading Turkish construction company which is the member of the Turkish Contractors Association (TCA). The company was founded in 1993 to make investments in construction, energy, natural gas, infrastructure, and manufacturing fields. Company has extensive construction projects in every region of Turkey by achieving a total volume of 3.000.000 m^2. The aforementioned projects cover construction of highways, bridges, crossroads, hospitals, hotels, schools, housing, dams, hydroelectric power plants, light rail, metro and tram systems, natural gas supply projects, intelligent buildings, water treatment plants and city networks such as water, and electricity. Company has significant experience and knowledge about Public- Private-Partnership (PPP) and privatization. In addition, company plays an active role in energy sector of Turkey by carrying out several investments and projects as a project developer, investor, producer, and entrepreneur with international financial institutions, and with international and global partners. Energy plants investments projects of the company include, renewable energy generation, energy trading, natural gas distribution, petroleum, fields of wind, hydroelectricity, geothermal and thermal energy as well as new energy sources such as solar and biomass energy.

7.2. Overview of the Project

Project is a housing project carried out in Ankara, Turkey. The start date of the project is 7 July of 2008. Scheduled duration of the project is 48 months. Contract price of the project is around 700.000.000 US Dollars and project size was defined as large-size. The contract type is Design Build (DB) and payment type is Lump Sum (LS). Company takes role in the project as designer and contractor. Owner of the project is the Republic of Turkey Prime Ministry Housing Development Administration.

7.3. Methodology of the Case Study

A face-to face interview and a tool use session was conducted with the company expert to gather the information and data of the project. The company expert knew the company practices as well as took an active role throughout the project lifecycle. The interview lasted about 2 hours. Firstly, the risk mapping tool was overviewed and its functions were introduced to the expert. After giving brief information about the risk mapping tool, the contexts of the case study and expectations from the expert were explained. The questions asked to the experts were in accord with the risk map structure as well as the vulnerability-vulnerability source framework. Expert was requested to give information about vulnerability sources and associated attributes that were existent or occurred in the project as well as rank the relevant attributes by means of their influence on the project. In addition, the expert was asked to utilize lessons learned database while deciding on the level of vulnerability source ratings. In this section, firstly, comments of company expert on vulnerability source attributes are given and then decisions on the retrieved project cases are exemplified.

7.4. Discussion on Vulnerability Source Attributes

Comments of company expert on each vulnerability source attributes are given as verbal statements as follows;

VS1. Instability of Economic Growth: The level of gross domestic product (A1), level of inflation (A2) or level of international trade and foreign investments (A5) did not influence the project performance significantly. However, instability of foreign exchange rates influenced the project as the construction materials were procured in different schedules based on foreign currency (A2). In addition, there were significant amount of financial expenses as the variations in the interest rates resulted in additional costs (A3). Expert decided to rate 'instability of foreign exchange rates' as high (4), 'instability of interest rate' as very high (5) and for all other attributes as very low (1).

VS2. Instability of Government: Although political conditions were stable during project lifecycle, still it had slight importance on project performance. Expert decided to rate 'instability of government' as low (2) without separately rating associated attributes.

VS3. Instability of International Relations: As the project was not an international construction project, variations among international relations did not have significant importance on the project performance. Although, construction materials did not imported from other countries, their prices were based on the foreign currency. Thus, instability of international relations had a slight effect on the material prices. Expert decided to rate 'instability of international relations' as low (2) without separately rating associated attributes.

VS4. Social Unrest: Although, it was not occurred during project lifecycle, high level of wage inequality might be resulted in quit of workers from the project (A21). Due to governmental policies, nationwide strikes generally do not occur (A22). Although, there exits civil wars (A23), protest and demonstrations(A24), income inequality (A25), education and health inequality (A26), gender inequality (A29) in the country it was not a risk to the project. Although, there exits labor market discrimination in the country (A28), the characteristics, and attitudes of the workers was known, thus it was not affected project significantly (A28). Although, due to governmental policies the racial diversity in the country may be a problem, it does not occurred during project lifecycle and did not influence the project performance (A20). Expert decided to rate 'high level of wage inequality' as moderate (3), 'high level of racial inequality' as low (2) and for all other attributes as very low (1).

VS5. Level of Bureaucracy: Although, government departments require excessive approval procedures (A31), the approvals could be taken immediately (A32). The work permits for labors could be obtained easily and quickly (A33). As the company was experienced in carrying out projects, excessive approval procedures, and government policies was not a problem (A34). Existence of variations of regulations among states is not applicable for Turkey (A35). Expert decided to rate 'highly fragmented governmental structure' as low (2), 'slow permits by government departments' as high (4), 'excessive approval procedures and government policies' as low (2) and for all other attributes as very low (1).

VS6. Immaturity of Legal System: Due to ineffectiveness of the legal system and immaturity of the legal framework, several problems were occurred during project lifecycle (A41, A42). Some problems about the project location were occurred and due to slowness of the legal system, they could not be solved in time. Expert decided to rate 'immaturity of legal system' as high (4) without separately rating associated attributes.

VS7. Restrictions for Foreign Companies: As the project is a domestic project, company did not have to obtain special work permits for local partners (A44, A45), special residency permits for accommodation (A46), or construction license (A48). In addition, as the company has experience about the business conditions of the country; neither local tax (A47) nor import and export requirements (A49) were a problem for the company. Expert decided to rate 'restrictions for foreign companies' as very low (1) without separately rating associated attributes.

VS8. Unavailability of Local Material: The company did not need to import construction materials as the local materials are available in the country (A50). As the company has been carried out several project in this country, company know from where (A51) and how to manufacture materials (A51), how to deliver them to the construction site (A52) and where to store these materials (A53). Thus, unavailability of local material is not a significant issue for the company. Thus, expert decided to rank all attributes of 'unavailability of local material' as very low (1).

VS9. Unavailability of Local Equipment: Similar to the manufacture of local materials, company did not faced any difficulty in providing equipment such as shortage of equipment (A54), delay in manufacture (A55), equipment delivery problems (A57) or low productivity of local equipment (A58). In addition, company had competent operator team who are experienced in using that type of equipment (A56). There were equipment services that provided proper maintenance facilities as well as equipment spare parts (A59). Finally, as the project is a housing project, there is no need for specialized equipment (A60). Thus, expert decided to rank all attributes of 'unavailability of local equipment' as very low (1).

VS10. Unavailability of Labor: As the company generally carried out projects in Turkey, they worked with a fixed labor that is competent in their own works (A61). In addition, as the labor are Turkish, there is no need to obtain work permits for them (A63) as well as local protectionism among workers is not applicable (A65). Generally, country did not face high level of labor disputes and strikes (A64), thus it is not a significant variable that affect the availability of labor. In addition, although skilled workers require slightly higher level of wage than unskilled workers do, the wage of skilled works is not in considerable amounts (A62). Thus, expert decided to rank all attributes of 'unavailability of local labor' as very low (1).

VS11. Unavailability of Subcontractor: Although the hired subcontractors possessed technical competency (A68), has been experienced in their fields (A68) and carry out high quality works (A69), they were poor in managerial skills (i.e. poor communication and coordination) (A71) . The subcontractors were appointed in time (A70), thus it is not a triggering variable for the unavailability of subcontractor. In addition, expert viewed high level of bid variation of subcontractors as a non-applicable attribute for this project (A72). Thus, expert decided to rank all attributes of 'unavailability of local subcontractor' as very low (1).

VS12. Unavailability of Infrastructure: As the project was carried out in the capital city of a developing country, availability of infrastructure facilities was not a problem for the company. The city provides land and air transportation facilities (A74), sufficient water supply systems (A73), and sufficient communication (A76) and power facilities (A77). Although, capital city could not provide water transportation (A75), it is not a significant issue as the land transportation facilities were sufficient. Thus, expert decided to rank all attributes of 'unavailability of infrastructure' as very low (1).

VS15. Complexity of Design: One of the most important issues in the project was that, the high complexity involved in the project design. Plans involve moderate complexity as they involved several systems that influence each other (A78). Although, project participants carried out the project systematically, they were not experienced in understanding, interpreting and using specifications (A79). There were several changes in shop drawings and samples, and although structural drawings should be studied in design stage, most of them were had to be worked out in construction stage (A80). Few construction items possessed high technological requirements; however, the project itself did not involve high complexity as it was a housing project (A82). Thus, expert decided to rank 'complexity of plans' as moderate (3), 'complexity of specification' as high (4), 'complexity of shop drawings and samples' as high (4), 'technological complexity as low (2) and project complexity as very low (1).

VS16. Low Constructability: There were some minor changes in construction method (A83). As the same team was responsible from the design and project management facilities, there were not any communication problems (A84). The project technological complexity level is low as the project is a housing project (A85). As the company only interacts with the client as a project participant, design build method was selected and any communication problems did not occurred (A86). There were some location restrictions due to working in the city center. These restrictions were; working in a congested area, limited site access, limited working hours, existence of traffic and strict requirements to prevent excessive noise. There were some deficiencies among standards, codes, and specifications relating with construction methods and manufacturing (A88). The company had sufficient computer generated models in quantity and quality (A89). Expert decided to rate 'unsuitable construction methods/changes in method' as low (2), 'lack of knowledge about location restrictions' and 'incomplete specifications/design standards and codes' as moderate (3) and for all other attributes as very low (1).

VS17. Complexity of Construction Method: Transportation costs were extremely high, so company decided to select plant and equipment manufacturer offering least transportation cost (A90). As the project is a housing project, it did not require specialized equipment, technological methods, or special construction methods (A91). Expert decided to rate 'complexity of plant and equipment selection' as low (2), and 'complexity of project' as very low (1).

VS18. Uncertainty of Geological Conditions: Company selected site exploration method properly (A99), carried out site investigation properly (A92), implemented proper sampling methods (A95), conducted high quality in-situ and laboratory tests (A96, A97) and prepared well-structured site investigation reports (A98). In addition, there were not any observed site heterogeneities (A93) as well as test measurements were accurate and consistent with the soil conditions (A94). Expert decided to rank all attributes of ‘uncertainty of geological conditions’ as very low (1).

VS19. Strict Quality Requirements: As the company had to sell project products to the free market, they had to achieve high level of quality. Thus, company implement quality training programs (A100), developed proper quality assurance and quality control systems (A101), carried out quality inspection and testing (A103, prepared nonconformance reports (A105), aimed to achieve high degree of aesthetics (A107), and appointed quality management staff (A109). Thus, expert decided to rank all attributes of ‘strict quality requirements’ as moderate (3).

VS20. Strict Environmental Requirements: Environmental requirements were not strict as quality requirements. Within the context of the project, there were not any requirements of prevention of dust emissions (A110), development of environmental management system (A112), prevention of harmful gases (A113), saving threatened or endangered species (A117), saving historic properties (A118), development of green building facilities (A119), prevention of light disturbance (A120), or prevention of odors (A121). However, it is need to implement strategies to prevent noise (A114) and wastes (A115). Expert decided to rank ‘strict requirements for prevention of noise’ and ‘strict requirement for prevention of wastes’ as moderate (3) and for all other attributes as very low (1).

VS21. Strict Health and Safety Requirements: The health and safety requirements are strict as the workers had to work on high-rise buildings. Company had to implement special health and safety training program (A123), developed safety monitoring and reporting systems (A124), inspected hazardous and dangerous conditions (A125), prepared a project specific safety manual and distributed it to all workers (A127) and implemented safety signage and warnings at site (A129). Expert decided to rank attributes of strict health and safety requirements as very high (5).

VS22. Strict Project Management Requirements: As the houses should be put on the market as early as possible, time management is critical for the company (A130). Due to budget limitations, company had to implement well-structured cost management system (A131). As the company had to sell houses to the free market, they had to achieve high level of quality (A132). The company was a well-established company, it have competent technical and managerial team (A133). There was not any requirement for implementing risk management system (A134). There were strict requirements of a health and safety management system. Any problem regarding health and safety may lead to stop construction facilities. A part from the inspections made by supervisor of governmental departments, in-house inspections were made (A135). Company has already implemented well-structured procurement (A136), communication (A137) and scope management systems (A138), thus there was not any requirement about these issues. Expert decided to rank ‘time management system’ and ‘cost management system’ as high (4), ‘quality management system’ and ‘risk management system’ as low (2), ‘health and safety management system’ as very high (5), and for all other attributes as very low (1).

VS23. Vagueness of Contract Clauses: Company developed well-structured contract clauses (A139), project attributes, requirements, obligations of project participants were defined in contract clauses (A140), rights and duties of project participants, responsible participants from the variations, cost overruns were defined in contract clauses (A141), cost sharing issues such as fee agreement, fee payment method, claims, insurance, interest, expenses are defined in contract (A142), legalized management procedures (A143) and contractual relationship structure (A145) were defined properly. However, there were some ambiguities about claims and dispute resolution methods in contract clauses and company had to allocate additional costs, which were not its responsibility (A144). Expert decided to rank ‘poor definition of claims and dispute resolution method’ as moderate (3) and for all other attributes as very low (1).

VS24. Contract Errors: Company selected appropriate contractual procedure (A146), allotted sufficient contracting duration (A148), used standardized contract clauses (A149) and prepared sufficient amount of contract documents (i.e. contract drawings, standards, plans, written statements) (A150). However, there were some flaws in contract clauses (A147) leading to uncertainty about how the payments would be made to the participants. Expert decided rank ‘contract errors’ as moderate (3) without separately rating its attributes.

VS25. Technical Incompetency of Engineer: All engineering team had competent in their own fields. Engineers had sufficient experience in tendering process (A151), design process (A152), construction process (A153), cost estimation (A154), resource allocation (A155) and scheduling (A156). Expert decided to rank attributes of ‘technical incompetency of engineer’ as very low (1).

VS26. Managerial Incompetency of Engineer: Most of engineers had sufficient experience in their own fields (A157). Although engineers were technically competent and had enough experience, there were mostly poor in managerial skills. They could not provide right information at the right time (A158), most of the time they could not prepared documents at the right time (A159), and they could not alter with the changes and variations (A160). However, as they technically competent, they were able to control analyze and maintain documents and drawings (A161). Expert decided to rank ‘lack of experience of engineer’ as low (2), ‘poor coordination and management ability’ as very high (5), ‘poor documentation and delays in approval of documents’ and ‘poor problem solving and change management ability’ as high (4), and ‘poor control ability’ as moderate (3).

VS27. Engineer’s Lack of Financial Resources: Engineers did not have sufficient financial resources to cover immediate cash flow problems. (A162). Expert decided to rank the vulnerability source having magnitude of high (4).

VS28. Client Unclarity of Objectives: Client was able to define project scope completely and clearly, (A163), they defined specifically project objectives such as the planned finish time of the project, budget of the project and expected quality of the constructed buildings. They clearly defined project attributes such as where to construct buildings, when the construction would start etc. (A166). However, there was some missing contract terms that risk sharing among project participants and claim resolution methods were unclear (A165). Expert decided to rank ‘unclarity about contract terms’ as low (2) and for all other attributes as very low (1).

VS29. Client Level of Bureaucracy: Client possessed slightly high level of bureaucracy in approval procedures (A167), however getting permits and approvals from client did not take considerable time (A169). Although, client organization required excessive amount of paperwork in approval processes, it did not influenced the progress of the project considerably (A168). Expert decided to rank ‘excessive and complicated approval procedures’ and ‘slow decision-making in the client’s organization’ as low (2) and ‘slow permits by client organizations’’ as very low (1).

VS30. Client Negative Attitude: Company did not face any problem related with the attitude of the client. Client did not exhibit any unethical or dictatorial behavior (A170), it was easy to arrange meetings with the client representatives (A171), and they were competent in human resource management and leadership ability (A173). As the project participants were only the company and the client, clients' negative attitude towards project parties was not an applicable variable. Thus, expert decided to rank all attributes of 'client negative attitude' as very low (1).

VS31. Client Poor Staff Profile: Technical and managerial experience level of the client staff did not have considerable effect on the performance and the productivity of the project. Thus, expert decided to rank all attributes of 'client poor staff profile' as very low (1).

VS32. Client Unavailability of Financial Resources: Client was not responsible from financing the project. Project financing was sales-based; thus, the availability of financial resources of the client was not significant. Thus, expert decided to rank all attributes of 'client unavailability of financial resources' as very low (1).

VS33. Client Technical Incompetency: Client was able to prepare project plans (A189), to conduct feasibility study (A190), to involve construction stage (A192), to document and approve construction documents (A193), and to control construction site (A194). Thus, expert decided to rank all attributes of 'client technical incompetency' as very low (1).

VS34. Client Poor Managerial/Organizational Ability: It was not the clients' responsibility to identify the amount and type of the technical resources (A195**).** Although, client possessed slightly high level of bureaucracy in approval procedures, they could give instructions at the right time (A196). Client representatives could established communication systems with the company (A197), continuously involved to the project, attended properly arranged meetings (A199), monitoring the construction site facilities (A202, A203). Expert viewed attributes such as improper selection system for contractors, improper selection of project location and type as inapplicable. Thus, expert decided to rank 'client poor managerial and organizational ability' as very low (1) without using its attributes.

VS35. Poor Site Supervision: Although company developed a system to monitor and supervise staff and workers (A205) and the supervisor team had competent in their fields, again some problems related with workers, were occurred at the construction site (A206).

The construction team was able to control procurement of construction resources as well as able to check the consistency among design and construction facilities. However, some minor design errors were occurred at the construction site (A 207, A208). Expert decided to rank ‘poor site supervision’ as low (2) without using its attributes.

VS36. Lack of Site Facilities: Transportation facilities to the construction site were sufficient (A209). Company could also construction accommodation buildings (A210), administration buildings (A212) and temporary facilities (A213). However, due to working in the congested location, establishing storage places to handle materials and equipment was a problem for the company (A211). Expert decided to rank ‘lack of storage places’ as high (4) and for all other attributes as very low (1).

VS37. Contractor’s Lack of Experience in Similar Projects: Company has been carried out several housing projects. (A214). They carried out large construction projects previously (A215). Most of the projects of the company carried out in Turkey (A216). They conducted projects with using similar construction method, previously (A217). Expert decided to rank ‘contractors lack of experience in similar projects’ as very low (1) without using its attributes.

VS38. Contractor’s Lack of Experience in Country: Company has been carried out several construction projects in Turkey since the time it was established. Thus, company has knowledge about general information about the country (A218), its governmental structure and political conditions (A219), economic conditions (A220), business and financial conditions (A221), environmental, health and safety regulations (A222), market conditions (A223) and legal framework (A224). Expert decided to rank ‘contractors lack of experience in country’ as very low (1) without using its attributes.

VS39. Contractor’s Lack of Experience in Project Delivery System: Company had sufficient experience about the responsibility sharing among project participants in design build projects (A225). They knew the contracting system (A226) as well as potential risks (A227) of the selected delivery system. Expert decided to rank ‘contractors lack of experience in project delivery system’ as very low (1) without using its attributes.

VS40. Contractor’s Lack of Experience with Client: Company worked with the client in their previous projects. Thus, they had experience about the past performance (A228), attitude (A229), financial resources (A230), managerial skills (A231) and technical competency (A232) of the client. However, it was the first project that company carried out design build (DB) contract with the client. Thus, some problems were occurred in tendering and bidding process (A233) as well as in construction process. Expert decided to rank 'lack of knowledge about tendering and bidding behavior' as very high (5) and for all other attributes as very low (1).

VS41. Contractor's Lack of Financial Sources: Company faced financial shortage in some predefined payment periods (A234). During this period, company had to finance the project by taking loans from banks (A236). Although, financial risks were defined and interpreted in contract clauses (A237), financial plans were inadequate to visualize the income and outcome expenses (A239) and contingency amount for unexpected situations could not cover the additional costs (A238). There was not any financial problem due to client, as the client was not responsible from financing the project (A235). Expert decided to rank 'lack of short-term finance' and 'lack of an appropriate financial plans' as moderate (3), 'unavailability of funding source from lenders or banks' and 'lack of contingency funds for unexpected situations' as high (4) and for other attributes as very low (1).

VS42. Contractor's Lack of Technical Resources: Company did not face any difficulty in providing technical resources. All these resources were sufficient in quality and quantity (A240, A241, A242, A243, A244, A245). Thus, expert decided to rank all attributes of 'contractors lack of technical resources' as very low (1).

VS43. Contractor's Lack of Staff: Company did not face any difficulty in providing project staff. The staff employed in the project was sufficient in amount and productivity. (A246, A247, A248, A249, A250, A251, A252, A253). Thus, expert decided to rank all attributes of 'contractors lack of staff' as very low (1).

VS44. Poor Project Scope Management of the Contractor: With the properly arranged meetings (A255), requirements of each organization were captured (A254), in line with these requirements the scope of the project was clearly defined, verified, and controlled (A256, A257, and A258). Thus, expert decided to rank all attributes of 'poor project scope management of the contractor' as very low (1).

VS45. Poor Project Time Management of the Contractor: Within the project scheduling, all construction activities (A259), their durations (A260), required resources (A261) were defined by experienced planning engineer (A263). However, there were some unexpected situations related with the subcontractor, planned finish time of some activities were delayed (A260). In addition, due to financial problems, company had to revise the schedule several times (A262). Expert decided to rank 'poor estimation of activity relationship and durations' and 'lack of development and control of schedule' as moderate (3) and for other attributes as very low (1).

VS46. Poor Project Cost Management of the Contractor: All cost items were defined clearly (A268) and cost estimation was carried out by experienced engineers (A265) based on the appropriate cost estimation method (A267). However, there were some flaws in financial plans that they were inadequate to interpret income and expenses (A269). Thus, expert decided to rank 'lack of an appropriate financial plan' as moderate (3) and for other attribute as very low (1).

VS47. Poor Project Quality Management of the Contractor: Company implemented quality training programs (A271), developed proper quality assurance and quality control systems (A272), and the quality of the goods and services supplied by vendor was high, and all participants and staff carried out high quality works (A275). Estimation of cost of quality measurement (A276) and utilization of statistical methods (A274) were not perceived as significant variables by the expert. Thus, expert decided to rank 'poor project quality management of the contractor' as very low (1).

VS48. Poor Human Resource Management of the Contractor: The organizational structure of staff was well-defined as the company has been carried out their entire project with the same staff (A278). Company supervised workers by in-house audits during construction process (A279). Company provided career developments to their staff (A280), continuously motived, and encouraged their staff (A281) as well as provided educational programs for them (A282). Thus, expert decided to rank 'poor project human resource management of the contractor' as very low (1).

VS49. Poor Communication Management of the Contractor: Contractor company developed organizational communication structure (A284) and communication plan (A285) prior to the project initiation. Company continuously distributed information among staff

(A286) as well as reported performance data of construction site activities (A287). Thus, expert decided to rank ‘poor project communication management of the contractor’ as very low (1).

VS50. Poor Risk Management of the Contractor: Company did not have any developed risk management system. They did not carry out risk identification (A288), risk assessment (A289), risk response (A290), risk ownership allocation (A291), or risk monitoring (A292). However, as the project itself was not risky, or did not involve any high risk conditions or circumstances, lacking of a structured risk management system was not influenced the performance of the company significantly. Expert decided to rank ‘lack of risk identification system’, ‘lack of risk assessment system’ as moderate (3), ‘lack of risk response system’, ‘lack of monitoring and reviewing risks’ as low (2) and for other attributes as very low (1).

VS51. Poor Procurement Management of the Contractor: Due to strict time requirements, company had to buy some construction resources before the tendering type was defined (A295). Although procurement contracts were made at the end (A297), the procurement contract type was mostly defined when procuring goods and services (A296). Contractor did not face any difficulty when procuring equipment (A300), materials (A301) or hiring labors (A302). However, due to financial problems company faced with some problems when hiring subcontractors (A303). Expert decided to rank ‘poor selection of appropriate tendering type’, ‘poor selection of appropriate procurement contract type’ as moderate (3), ‘poor procurement of subcontractors’ as high (4) and for other attributes as very low (1).

Unexpected Events: During construction process, any wars, or hostilities, rebellion or terrorism, or natural catastrophes were either did not occurred or in case they occurred, did not have significant influence on the project performance. Expert decided to rank all vulnerability sources of ‘unexpected events’ as very low (1).

7.5. Discussion on Retrieved Past Project Cases from Lessons Learned Database

Within the context of use of the lessons learned database, company expert, firstly analyzed the retrieved case, then evaluated the similarity of their project with the previous project with the consideration of country conditions, as well as project and company characteristics. Part of the company expert discussion on the retrieve cases is given in this section. The discussion is related with the Case 1.1.that is stored in the database previously. The retrieved project is hydro electrical power plant project carried out in Turkey. Case is related with occurrence of landslides that caused blockages on the main road. Until the blockages on the road were removed, road could not serve transportation facilities, thus contractor company could not supply construction material and equipment to the construction site. The first problem related with this case is; only one road had access to the construction site. Second problem is; it was the first project that contractor carried out project in this region. First vulnerability existed in the case is unexpected events having source of natural catastrophes. Second, one is the unavailability of infrastructure relating with the adverse country related conditions. Final vulnerability is the contractor's lack of experience having source of contractor's lack of experience in country. All of these vulnerability sources have high (4) impact on the multiple consequences. Company expert discussed that; occurrence of natural catastrophes is not likely in the region that the project took place. Thus, expert decided to rank natural catastrophes as very low (1). In addition, as the project location is at the center of the capital city of the country, there are several access roads to the construction site. Expert decided to rank unavailability of infrastructure as very low (1). Finally, company has been carried out several projects in this country, thus they are experienced in doing business in this country. Expert decided to rank lack of experience on country as very low (1).

7.6. Findings and Discussion of the Case Study

Based on the discussions on the vulnerability source attributes and retrieved project cases from the lessons learned database, final ratings are determined by company expert. After using the lessons learned database, company expert argued that, ratings, which are defined using attributes, are reliable and represent real project conditions. Thus, these rating are fed into the tool, and ratings of the risk-related variables as well as cost overrun percentage are estimated through SEM. Figure 7.1 represents the findings of the risk assessment process utilized by the tool. The cost overrun percentage estimated by the tool is 11.4%. The real cost overrun percentage of the project is 15%. Although, additional case study approaches are necessary to ensure the reliability of the risk assessment methodology employed in the tool, the methodology at least highly forecasted the cost overrun percentage of this case study. To be noted that, justifying the reliability of the methodology of the tool is out of the scope of this study. In her study, Eybpoosh (2010) justified the tools' reliability via conducting several case studies and concluded that the tool can highly predict probable magnitudes of risk variables. In this research, the aim of conducting case study approach is to evaluate in what extent the vulnerability source attributes and lessons learned database is helpful when carrying out risk assessment. According to company expert, although some of the attributes are not applicable within the context of their project, still they are helpful in defining the magnitudes of vulnerability sources.

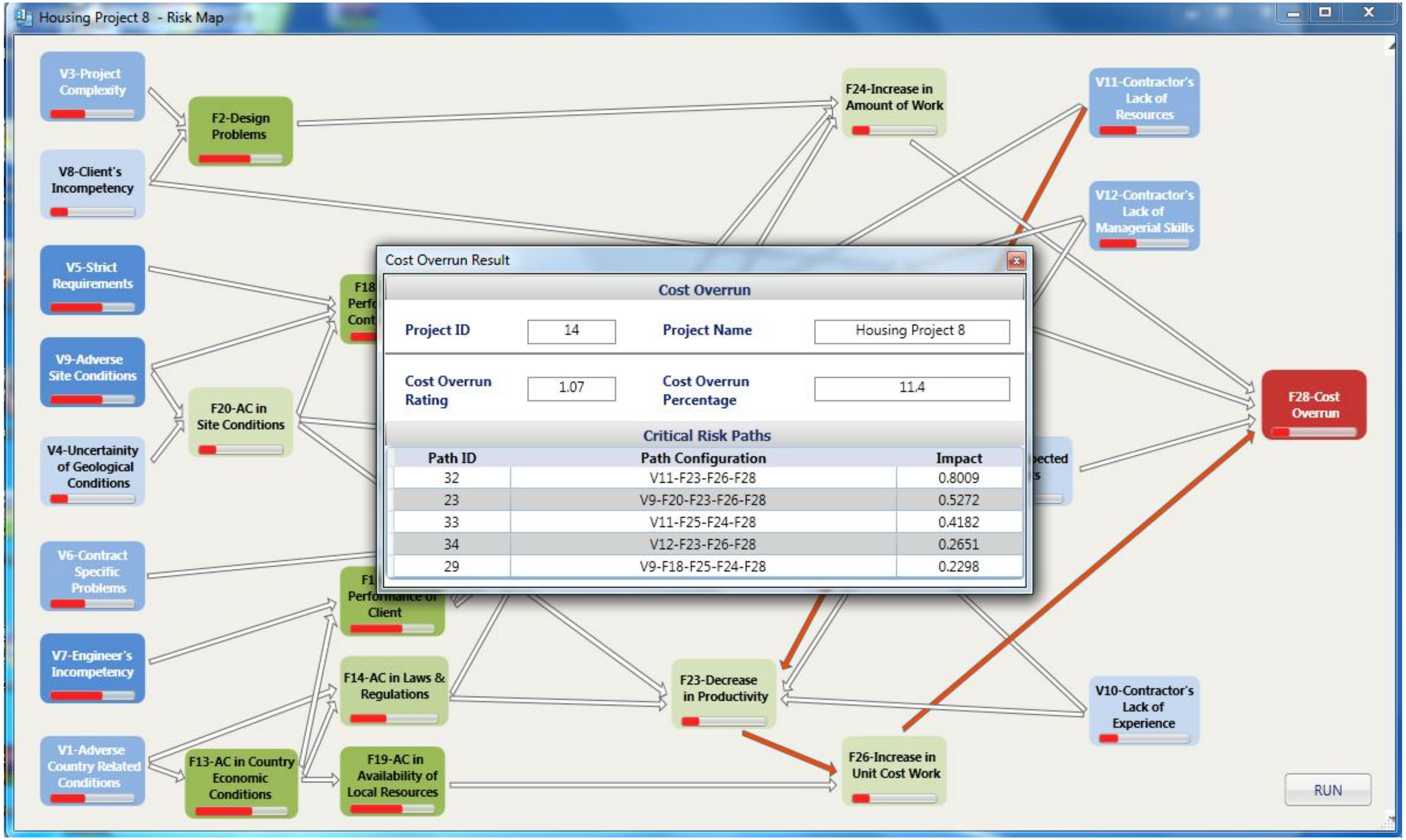

Figure 7.1: Risk assessment results of the case study

CHAPTER 8

CONCLUSION

Previous studies focusing on international construction projects confirm that, international projects subjected to additional risks that arise due to doing business in an external environment and under complex circumstances. Thus, simulation of consequences of probable risks in the earlier stages of projects by conducting risk assessment has an object attention in achieving project objectives in international projects. Within literature, several authors have been attempted to develop risk identification and assessment approaches/techniques, however they failed to reflect real project conditions and/or are limited in applicability and reliability in real projects. Some common shortcomings that hinders the effectiveness of these approaches/techniques are; (1) they rely on quantitative techniques (i.e. Sensitivity Analysis, Monte Carlo Simulation) that suffered from insufficient and subjective numerical data (2) they failed to consider causalities among risk factors as well as to cover interactions among risk paths and to demonstrate an overall risk map structure of the generated risk paths, (3) they rely on intuition, judgment and individual experience of decision-makers which brings subjectivity in assessment outcomes in some extents.

Various researchers, particularly those have been focused on construction risk management, recognize the cruciality of facilitating learning-based systems/database as a part of risk management process. Generally, the prevailing argument among these studies are, learning from past projects enhance the risk assessment process by making reuse of gained knowledge for forthcoming projects. Thus, the preferences of project managers would not solely based on self-intuition or experience, which makes projecting future circumstances in a more rational manner. In this thesis, it is argued that capturing the knowledge and experience gained in previous projects are essential to corporate risk event histories, to record the circumstances under which risks occurred, to understand cause effect relations between risk- related information and project outcomes, and to make available of past information for future use.

In addition, in current literature, several authors have been suggested to employ computer based software systems for the facilitation of risk management actions in a systematic and effective manner. Various authors (i.e. Akintoye and MacLeod, 1997; Leung and Chuah 1998; Al-Zarooni and Abdou, 2000; Jannadi and Almishari, 2003; Dikmen et al., 2004) criticized major drawbacks of traditional risk assessment methodologies and suggested to develop computerized tools to systemize the risk management practices. According to Akintoye and MacLeod (1997) computer-based tools have some superiorities over traditional methods such as less time involvement in risk assessment process, handling dynamic and uncertain environment of construction industry and enhancing the effectiveness of the risk management practices.

This study was an attempt to overcome the major drawbacks of existing risk management approaches by offering a knowledge-based risk mapping tool. The major objectives of this study can be summarized as follows;

(1) Developing a risk mapping tool that will be used to predict potential risk paths and cost overrun percentage of an international construction project. The tool employs a risk assessment methodology, which covers causalities among risk related concepts. The risk-vulnerability ontology proposed in Fidan (2008) and the risk map structure employed in Eybpoosh (2010) constitutes the foundation of the risk assessment methodology.

(2) Assisting decisions makers when quantifying the risk-related variables in the risk assessment process. Firstly, vulnerability source attributes are identified and then a prototype lessons learned database is developed. The lessons learned database utilizes previous know-how experiences of decision makers for future use by codifying, storing, and retrieving the captured experiences.

To achieve these objectives, this thesis was studied under three sequential steps: development of vulnerability source-attribute framework, development of lessons learned database, and development of knowledge-based risk mapping tool.

Prior to the presentation of the research methodology, this thesis began with the literature review on the concept of risk and risk management. Within this chapter, objective and importance of risk management were discussed as well as previous risk management approaches were introduced. In addition, research objectives of this study were announced by discussing the major shortcomings of the current risk-based approaches as well as giving the discussions conducted with the partner firm experts. Finally, risk-vulnerability ontology proposed in Fidan (2008) and the risk map structure developed in Eybpoosh (2010) were introduced to give introductory information about the risk mapping tool.

In the third part of the study, vulnerability source-attribute framework was intended to be developed. The concept of attribute and importance of attribute identification was introduced and previous studies focusing on attribute identification was given. An identification test was facilitated to explore attributes of vulnerability sources from the available literature. In addition, the applicability of the identified attributes was justified along with the one of the illustrative example of a project that had been captured through the case studies conducted with partner firm experts. The identified attributes will further be used in the risk assessment methodology employed in the knowledge-based risk mapping tool in order to assist decision makers in assessing the magnitudes of the vulnerability sources.

In the fourth part of the study, the underlying theory of the knowledge management and the methodology for development of the lessons learned database of the risk mapping tool were explained. In the first section of this chapter, concept of the knowledge management and, knowledge management techniques in construction industry were introduced as well as the necessity of implementation of such techniques and its challenges in construction industry was discussed. In the second section existing literature relating previous learning based risk management approaches in construction projects were reviewed. In the third section, objectives of the development of a lessons learned database within this study, was announced. Finally, the methodology for the development of the database is explained and an illustrative case study approach was given to show how such a database was established. To be highlighted that, the lessons learned database incorporated in risk mapping tool is aimed to enhance risk management practices of construction practitioners by assisting them in risk assessment process and facilitating organizational learning.

In the fifth chapter, the risk mapping tool was introduced that has been developed to enhance the course of risk management and assist practices of construction practitioners in international construction projects. In the first section, fundamentals of the tool were given. In the second section, the risk management process employed by the risk mapping tool was explained by presenting the process model of the tool. In third and fourth sections, the architecture of the tool as well as operational steps of the tool was described. The risk mapping tool addresses four consecutive steps in operation: (1)defining project information, (2)entering past project histories into lessons learned database,(3) carrying out risk assessment by using vulnerability source attributes and/or retrieving similar past projects from lessons learned database, (4) evaluating risk assessment results. The tool can also be used to carry out sensitivity analysis. It also provides an automatic report documentation system to share and transfer risk assessment results or past project cases stored within the database among the organization.

Sixth chapter presented the evaluation of the usability of the risk mapping tool through conducing laboratory testing sessions as well as post-task and post-test questionnaires. Prior to the introducing the methodology of conducting usability testing, firstly the concept of usability and usability testing was introduced. In accord with the methodology offered in the existing literature, some quantitative and qualitative goals were determined to measure the ease of tool operations and to understand the satisfaction level of tool users. The first step in usability testing was conducting laboratory testing sessions to quantify how effectively the major functions of the tool could be facilitated and how quickly they could be completed by test participants. After completion of each test scenario, post-task questionnaires were filled out by test participants to capture subjective responses of them on usability attributes of the tool.

Finally, a case study was conducted with a company expert who takes part in a leading Turkish construction company. Within the context of the case study approach, firstly in-depth interview and tool use sessions were carried out repetitively. The case study was adopted to predict cost overrun percentage of a real construction project as well as to understand how the vulnerability source attributes and lessons learned database can assist decision makers in risk assessment process

8.1. Expected Benefits of the Risk Mapping Tool

The risk mapping tool has been developed to enhance the course of risk management, increase effectiveness of risk management workflow as well as assist practices of construction practitioners in international construction projects. The features and expected benefits of the tool, as mentioned by the experts in the partner firm can be summarized as follows:

Systematic risk identification and classification

According to Nielsen (2006), the most common problem of risk management practices in project construction stage is the insufficient risk identification activities. The majority of the existing researches offer risk identification methodologies; however, they are lack of comprehending the probable risk variables emerging in international markets. Thus, decision makers mostly had to identify risk variables by themselves that tended to cause ineffective, inadequate or insufficient risk identification practices. The risk map offered in this study, provide an effective way to visualize risk-related parameters and risk paths that may emerge in real projects. Thus, contrary to traditional risk management approaches, by using risk map decision makers would not identify construction risks themselves which avoids the probability of inadequateness of risk management practices due to poor risk identification performance. Within the risk map, risk related variables are classified in accord with the causality among them, such as vulnerability, risk source, risk event and risk consequence. All variables are represented on the risk map with different colors to give a better understanding of risk types. In addition, vulnerability sources are defined to represent the associated vulnerabilities as well as each source is characterized with a certain list of attributes. Thus, risk map provides a standard vocabulary for decision makers by defining risk related variables, vulnerability sources, and associated attributes.

Improvement of organizational learning

The lessons learned database can improve organizational learning and develop a common organizational behavior regarding risk management by developing an organizational risk memory. With the use of the database, all members of an organization can store knowledge and experience gained in previous projects. Lessons learned in previous projects can be shared and transferred to other project, team members or organizations via automatic report generation system so that continuous improvement of database and organizational learning practices can be achieved. By incorporating experiences of several decision-makers, the database provides a knowledge capturing platform that facilities company level learning system. With the use of lessons learned database, it is expected to reduce forthcoming reworks by avoiding the repeat of past mistakes. By storing know how of the experiences of decision makers, the threat of knowledge loss can be minimized. According to Disterer (2002) even if the project information is documented, the place where the documents are stored might be unknown and it would be difficult to access employees who are responsible from tasks and worked on the project. Within this context, a case library is developed to make use of the previous projects and enable to examine the information and associated cases of these projects.

Guidance on risk assessment process

The lessons learned database is developed and vulnerability source attributes are identified to assist decision makers when quantifying the vulnerability sources. The database is expected to aid decision-makers by retrieving and making use of the knowledge of previous projects that have been captured, codified, and stored within the database previously. With the retrieved similar projects, decision makers can examine the risk events occurred in the previous projects as well as by comparing the conditions of the existing project with the similar previous project, can make decisions that are more reliable on the magnitudes of the vulnerability sources. In addition, to give a better understanding of the vulnerability sources, a list of attributes that indicate the triggering events or conditions of the relevant vulnerability sources, is identified. When the attribute weights and ratings are fed into the tool, the magnitudes of the vulnerability sources will be quantified automatically. Finally, tool provides an automatic sensitivity analysis function that quantifies the variations on the cost overrun percentage with the changes in the magnitudes of the vulnerability sources. Thus, decision makers can evaluate the most significant vulnerability sources that highly contribute to the cost overrun percentage, and may implement some mitigation strategies to minimize the magnitude of these sources.

8.2. Research Limitations

The proposed risk mapping tool can enhance the effectiveness of risk assessment process by assisting decision makers when quantifying the probable magnitudes of risk related variables. The vulnerability source attributes and lessons learned database could aid to improve the reliability of the assessment outcomes by incorporating previous experiences or giving a deep understanding about the variables. However, comparing similar previous projects with a fortcoming project or deciding on the magnitudes of attributes contain self-intuition and experience of decision makers that lead to assessment outcomes still depend on subjective judgment of decision makers.

Lessons learned database could support decision makers in the extent of number of risk event histories accumulated in the database. To enhance organizational knowledge, decision makers should supply and acquire knowledge into the database after completing a task or a project. In addition, in case of number of cases in the lessons learned database is low, and then similar cases could not be retrieved. Thus, as knowledge would be stored or shared continuously, the organizational risk memory and knowledge increases as well as the tool could offer a better assistance next time when assessing risk-related variables. In addition, lessons learned database should be improved to take into account of complex conditions resulting in risk consequences and in number of cases to retrieve similar cases.

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APPENDIX A

This chapter presents findings of the third chapter of this study. As it was announced in the third chapter, this chapter gives vulnerability source attributes along with their detailed descriptions from Table A. 1 to Table A. 49.

Table A. 1: Attributes of 'VS1- Instability of Economic Conditions'

Name	Description
Low level of gross domestic product	Gross domestic product refers to the total value of domestically produced products and service outputs of a country. A higher gross domestic product may represent high level of production, a healthier economy, and positive economic growth of a country.
Instability of foreign exchange rates	Foreign exchange rate is the rate at which one currency will be exchanged for another. Exchange rate of a country will change while one of the two constituent currencies changes. Exchange rate fluctuations generally occur due to the variations in the demand and supply balance of the currencies.
Instability of interest rate	Interest rate refers to the "rate at which interest is paid by a borrower for the use of money that they borrow from a lender". Political short-term gain, deferred consumption, inflationary expectations, and liquidity preferences are some triggering factors of interest rate fluctuations.
High level of inflation	Inflation refers to an increase in the total money stock which results in the increase of goods and services price over a period. Inflation rate of country is interrelated with the interest rates, rate of return, currency exchange rates, level of economic activities, and level of investment capability of a country.
Unsatisfactory level of international trade and foreign investments	Level of international trade or foreign investments in goods and services, are some variables to predict future economic activity of a country. 'Low export rates' is an indicator of unsatisfactory level of international trade which may be result in limited economic activities.
Instability of political conditions	Irregular political changes might result in market uncertainty, low gross domestic product values, interest rate fluctuations, arising investment barriers, which in turn might disturb long-term finance and economic activities of a country.

Table A. 2: Attributes of 'VS2- Instability of Government'

Name	Description
Poor support for government	Government might take support of public (i.e. voting for the same political party at the time of next election) by enhancing economic and social developments. Socioeconomic developments can be related with the; level of gross domestic product, life expectancy, literacy rate, employment, personal safety, civil rights, health care and so on.
Lack of government continuity	Continuity of the political system can be measured by the number of years that the same political party remains in government or power. Dictatorships that last at least 25 years and very seldom government and cabinet changes can be characterized as a stabilized political system.
High level of revolutions in the history of the country	Revolution refers to the abrupt and immediate change of the social structure of a country, generally with violence, due to discontent and dissatisfied public.
Occurrence of civil wars	Civil war refers to the political demonstrations and wars within the different region of the same country. Position of the government might be vulnerable to instability, in case of the existence of civil wars.
High level of nationwide strikes	Nationwide strike refers to the act of stoppage of work in order to represent the requirements and demands of public to the government. Position of the government might be vulnerable to instability, in case of the existence of nationwide and labor strikes especially ones that are encouraged by unions.
High level of riots	Riot is an act of public disorder, which is formed by disorganized groups with a sudden act of violence to the authority (government) or people. Riots might occur due to poor living and working conditions, conflicts among ethnic groups or religions or dissatisfactions with the government.
Dissatisfaction from the economic indicators	Economic development is a crucial indicator that might be used to measure political stability. Some economic indicators are; long-term growth rate of GDP per capita, GDP growth rate, level of initial GDP per capita, investment rate, inflation rate, index of economic freedom, and currency exchange rate.

Table A. 3: Attributes of 'VS3- Instability of International Relations'

Name	Description
Lack of alliances	Countries might integrate or adjoin by alliances with the aim of coexisting with each other. Collaboration of countries through alliances such as European Union, NATO and WTO, might contribute to implement more stronger and stable international relations.
Poor role of country for the globalization	Globalization and its outcomes (i.e. increasing worldwide technology, communication systems, and travelling and business opportunities) might establish relations among countries. Countries, which take a considerable role for the globalization, can more easily develop economic, political, and social international relations.

Poor trade relations	Countries can implement trade relations by importing and exporting products, goods, and services. Any import and export restrictions, especially restrictions on critical trade facilities (i.e. import and transportation of gas, energy, or oil) might damage relations among countries.
Negative declarations of media	The attitude of publications and declarations of mass media have profound effect on the relations among countries. An adverse attitude or an opposing manner of a media of a country towards another, might damage their international relations.
Level of threats for national security	The arm force of a country might be a threat for other countries in such cases; implementing nuclear power programs, enabling illegal arming that may be facilitated in terrorism objectives, and serving hostile and aggressive attitude of the country.
Poor economic relations	Economic relations can be established by encouraging foreign investment decisions, establishing import and export activities, and implementing economic policies. Economic policies can support international relations by creating business opportunities such as entering into an international market, carrying out an international trade, or initiating a foreign investment.
Undesirable history of country	Existence of wars or controversies is one of the undesirable events in the history of countries. These might have an adverse effect on the relations among countries at present, if they could not reach in an agreement with which all of them are satisfied.

Table A. 4: Attributes of 'VS4- Social Unrest'

Name	Description
High level of wage inequality	Wage inequality refers to the unequal distribution of wages among specific group of worker or employer in a society or a country.
High level of nationwide strikes	Nationwide strike refers to the act of stoppage of work by a specific group with the aim of making employer or government aware of dissatisfaction or disputes.
Occurrence of civil wars	Civil war refers to the political demonstrations and wars between specific groups of people who are from different region of the same country.
High level of protests and demonstrations	Protests and demonstrations are coordinated by a group of people with the aim of expressing their disapprovals or claims and making the authority aware of their rights.
High level of income inequality	Inequality of income distribution highly observed between rural and urban areas or interior and coastal provinces. Generally, investments are highly preferred to be made at urban areas or/and coastal provinces rather than rural areas or/and interior provinces. These preferences might create a wide job opportunities and income distribution gap among areas and provinces.
High level of education and health inequality	Education and health inequality refers to the unequal distribution of health and education facilities and opportunities among the different region of the same country or among the different groups of people.

Lack of institutions that protect human rights	Aim of the institutions that protect human rights can be listed as, to denote the inequality level of income, to provide education and health opportunities, to narrow the gap between the social classes, to solve social conflicts and to protect the social groups' rights.
High level of labor market discrimination	Labor market discrimination refers to the preference of employers from the dominant group or men rather than ethnic minorities or women, which might result in widening the income gap between gender or ethnic groups.
High level of gender inequality	Gender inequality refers to the unequal distribution of opportunities among men and women in areas such as economics, education, social life, business life, and politics.
High level of racial inequality	Racial inequality refers to the discrimination of a group of people due to their racial characteristics such as skin color, physical appearance, or culture.

Table A. 5: Attributes of 'VS5- Level of Bureaucracy'

Name	Description
Highly fragmented governmental structure	Fragmented structure of a government can be in the form of the cabinet departments, corporations, regulatory agencies, executive agencies or in the central, provincial, city and municipal levels.
Slow permits by governmental departments and agencies	A slow permit from government refers to the delay in approval of documents, reports, or permits from agencies and departments. High level of bureaucracy might lead to a time-consuming approval process, due to necessity of examination and control of each document.
Excessive time of obtaining permits for laborers	Obtaining permits for laborers might occupy excessive time; in the case of having requirements of work permits for foreigners, an employment contract or a special residency permit.
Excessive approval procedures and government policies	Obtaining approval might involve considerable bureaucratic works, in case of the existence of excessive approval processes or high level of policies or regulations imposed from governmental departments.
High level of variations of regulations among states	Each level of governmental structure (i.e. central, provincial, and local) might apply different laws and regulations, which might also contradict each other in some cases.

Table A. 6: Attributes of 'VS6- Immaturity of Legal System'

Name	Description
Insufficient law for joint ventures	The legal framework of the country should cover the rights and obligations of joint venture participants to avoid possible uncertainties. Laws should comprehend the management of claims, disputes, disagreements, conflicts and contract related problems.
Lack of independence of the judiciary	In order to enable certainty of courts and fairness of court justice, judiciary should not be subjected to or influenced by the other governmental departments or branches

High level of changes in law	'Changes in law' refers to the frequent changes in governmental policies, regulations, and legislations. These policies can be related with the environment protection, health and safety considerations, worker protection, employment system, working conditions or economic parameters.
Existence of corruption	Existence of corruption refers to the exercise of any unlawful or illegal influence such as offering any bribes or any illegitimate agreements to the project developer by governmental departments or representatives.
High level of variations of regulations among states	Each level of governmental structure (i.e. central, provincial, and local) might apply different laws and regulations, which might also contradict each other in some cases.
Ineffectiveness of the legal system	Legal system should not be lengthy, expensive in process, ineffective in enforcement mechanisms, and inconsistent in terms and conditions.
Immaturity of legal framework	Regulations arranging the actions of making investments, doing business or carrying out a construction project should not be primitive in order to avoid frequent changes. Laws and regulations should be unified, comprise obligatory terms and conditions, and preferably comply with the international legal framework.
Lack of coherence of order and justice	In order to satisfy the coherence of order and justice, countries might undergo same diplomacy, support same international organizations, or operate an international law and legal framework.

Table A. 7: Attributes of 'VS7- Restrictions for Foreign Companies'

Name	Description
Strict requirements to obtain work permits	Some strict requirements imposed from host countries to the foreign firms or entities are; requisite of collaborating with a local partner, signing an employment contract, obtaining an employment certificate that shows workers' competency level. In an employment contract, job specification and working period of each worker shall be defined. An employment permit is required to be issued by a local sponsor or partner. Foreign firms, agencies are not allowed to be a sponsor. In foreign employment certification, labors' responsibilities and work related restrictions should be defined.
Strict requirement for local partners	Requirement of appointing a local partner by foreign firm or entity is one of the prerequisites to do business in some countries. In addition, a local partner shall be appointed as the project contractor, who has the authorization to control and manage the project. However, the start-up investment is not under the responsibility of the local partner.
Strict requirement of a special residency permit	The applicant must have a formal job offer in order to apply for a residency visa or permit. In some situations, applicants should also submit the evidence of their professional and academic qualifications and undergo a medical examination.
Strict requirements regarding local tax	The contractor is required to pay some taxes such as income tax, withholding tax, entry tax, service tax, state tax, corporate tax, national gas investment tax, property tax, branch remittance tax, real estate tax, foreign sourced income tax, or Zakat tax.

Strict requirements to obtain construction license	In order to obtain a construction license, contractor firm should provide some documents regarding the feasibility study, outline of ventures' proposed capital structure, partnership agreement, and assurance of training of local workers, foreign certificate of registration, procurement plans for machinery, and other equipment.
Import and export restrictions	The import of certain products might require special permissions. On the other hand, the import of some other products might be totally prohibited. Prohibition of some goods, generally prevail in countries ruling Islamic regime. Alcoholic drinks and the meat of swine (porcine animals, pigs) are among some common prohibited products. The imports of books, magazines, films, and pharmaceutical products, fresh and deep-frozen food are some products requiring special permits.

Table A. 8: Attributes of 'VS8- Unavailability of Local Material'

Name	Description
Shortage of material in the host country	Contractor can be forced to rely on local materials, in the case of facing with import restrictions or prohibitions. Contractor must investigate the local materials in advance to avoid any difficulties regarding unavailability of construction materials in the host country.
Delay in the approval/manufacture of materials	Contractor might face with some problems during taking approval and manufacturing of materials due to the high level of bureaucracy involved in governmental departments, poor procurement methodology implemented by a local partner or high degree of custom restrictions.
High level of material delivery problems	Contractor might encounter with some problems during transportation of materials due to the unfamiliarity with the territory, long transportation times, poor road conditions, lack of signposting, pilferage, or banditry. In addition, special temporary roads might need to be constructed in the case of very remote construction sites.
Damage of materials in storage	In order to store materials in safe conditions without any permanent or temporary damages, special services shall be provided.

Table A. 9: Attributes of 'VS9- Unavailability of Equipment'

Name	Description
Shortage of equipment in the host country	Contractor can be forced to rely on local equipment, in the case of facing with import restrictions or prohibitions. Contractor must investigate the availability of the local equipment (i.e. excavators, crane shovels, draglines, cranes, dozers) in advance.
Delay in the approval/manufacture of equipment	Contractor might face with some problems during taking approval and manufacturing of equipment due to the high level of bureaucracy involved in governmental departments, poor procurement methodology implemented by a local partner or high degree of custom restrictions.
Unskilled Operators	Trained and skilled foreign operators might be required for some specialized equipment in order to achieve expected efficiency and productivity, in the case of unavailability of skilled workers in the host country.

High level of equipment delivery problems	Contractor might encounter with some problems during transportation of equipment due to the unfamiliarity with the territory, long transportation times, poor road conditions, lack of signposting, pilferage, or banditry. In addition, special temporary roads might need to be constructed in the case of very remote construction sites.
Low productivity and efficiency of equipment	In the long term, project delays might occur in the case of low productivity and efficiency of equipment provided by the host country. In addition, inaccurate prediction of equipment production rate and wrong equipment choice might lead to time delay.
Improper maintenance and lack of spare parts	Equipment maintenance refers to the servicing, adjusting and repairing of the equipment by a service team or maintenance technicians. Local maintenance teams should be trained and possess technical competency. In addition, considering the difficulties regarding supplement of spare parts of equipment, the contractor should establish spare parts stock age policies at the earlier stages of the project.
Requirement of specialized equipment	The procurement of some required special equipment, unavailable in the local market, might occupy a considerable time.

Table A. 10: Attributes of 'VS10- Unavailability of Labor'

Name	Description
Shortage of skilled labor	Trained and skilled foreign laborers might be required for some specialized construction works in order to achieve expected efficiency and productivity, in the case of unavailability of skilled workers in the host country.
High wages of skilled workers	In case of skilled workers require high wages; budget limitations may force contractors to hire unskilled workers or less number of skilled workers.
Strict requirements to obtain work permits	Some strict requirements imposed from host countries to the foreign firms or entities are; requisite of collaborating with a local partner, signing an employment contract, obtaining an employment certificate that shows workers' competency. In an employment contract, job specification and working period of each worker shall be defined. An employment permit is required to be issued by a local sponsor or partner. Foreign firms, agencies are not allowed to be a sponsor. In foreign employment certification, labors' responsibilities and work related restrictions should be defined.
High level of labor disputes and strikes	Occurrence of conflicts among workers or authority dissatisfactions of workers might lead to labor disputes and strikes at the construction site. In case of the inexistence of a labor union in the host country, any negotiations cannot be performed among workers and the authority, to solve the possible problem.
High level of local protectionism	Local protectionism refers to the requirement of the host country from foreign firms/entities to hire local workers. In this case, if the local workers are not skilled or experienced overall productivity or quality of the construction facilities might decrease.

Table A. 11: Attributes of 'VS11- Unavailability of Subcontractor'

Name	Description
Lack of priority of the project	Subcontractor might have tight schedules to carry out required tasks due to their any other local on-going projects. In this case, subcontractor's level of priority given to the project is an important determinant to perform the required tasks in expected quality and in pre-defined schedule.
Poor technical skills and experience of subcontractors	Subcontracts are generally hired for specific work items of a construction project such as installation of electrical, heating, plumbing and ventilation systems. Subcontractors should have sufficient knowledge about technical requirements, work methods, and processes. They must have the ability to define and provide materials and required machinery.
Poor quality of subcontractors	Subcontractor quality is related with the subcontractors' ability to perform required task and to deliver products to meet project requirements. Quality of subcontractors can be examined under three different categorizes; technical, functional and workmanship quality. Technical quality refers to the quality of materials, used components, fittings, and finishes performed by subcontractors. Functional quality is related with the reaching the intended project objectives. Workman ship quality determines the level of experience and technical competency of the hired workers.
Delay in appointing subcontractor	If the local subcontractors are required to be appointed from the host country, selection of the most suitable ones might occupy considerable time in the case of unavailability of sufficient experienced subcontractors. Additionally, in the case of working with foreign subcontractors, if host country regulates strict requirements, providing work permits or signing an employment contract might also occupy considerable time.
Poor managerial skills of subcontractors	Subcontractors should have ability to cope with working on several sites by managing their technical resources such as equipment, materials and labor.
High level of bid variation of subcontractors	Variation in subcontractor bid prices in high ranges, might take considerable selection time of general contractors or owners.

Table A. 12: Attributes of 'VS12- Unavailability of Infrastructure'

Name	Description
Shortage in water supply	Some of the water facilities, which should be supplied both inside and outside of the construction site are; direct water connection from water supply network, waste water system by piped sewage network, ground water drainage network, surface water drainage network especially during period of rain, water storage, and pumping, water protection especially during winter period, and water distribution for firefighting.
Unavailability of land and air transportation	Availability of land and air transportation refers to the existence and access of transportation facilities such as road networks, airports, highways, railways and seaports. Some crucial considerations, which determine the availability and quality of the transportation services, are total length of roads, railway lines, and capability of airports.

Unavailability of water transportation	Transportation facilities might rely on water, in case of countries or geographic regions that are restricted or inefficient in other transportation alternatives. Despite the fact that, ports and harbors can be notoriously overcrowded in such countries; construction materials, fuels, raw materials can be supplied by water transportation.
Unavailability of communication facilities	Some communication facilities, which should be supplied both inside and outside of the construction site, are; telephone mainlines, mobile telephone services and internet penetration.
Unavailability of power	Availability of power refers to the availability of energy sources such as gas and electricity within the required consumption rate. Power can be generated internally in a country and/or imported into the country from external generating sources. Contractor or client should determine whether sufficient power and transmissions lines exist in the host country for delivery of power to the construction site, or new generation capacity and new transmission lines will need to be built.

Table A. 13: Attributes of 'VS15- Complexity of Design'

Name	Description
Complexity of plans	Construction plans are drawings, which represent the location, dimensions, and details of construction tasks. Plans include site and detailed working drawings that represent structural, electrical, and mechanical work items. Design drawings and details should be clear, sufficient and comprised in order to avoid any complexity.
Complexity of specifications	Construction specifications are the written procedures, in which detailed materials, equipment, and workmanships requirements were explained. Plans must be used together with specifications in order to avoid complexity.
Complexity of shop drawings and samples	Shop drawings are drawings or charts, which are prepared by a contractor or a supplier. Shop drawings represent detailed characteristics of equipment or structural elements that are needed to be fabricated or installed. However, samples are physical examples of materials and equipment, which are generally submitted to the contractor in order to be approved.
Technological complexity	Projects that require high level of innovation or aimed to meet high technological standards can be a source of complexity.
Project complexity	High technical complexity level of projects (i.e. petrochemical plant, large power plants, large-scale infrastructure projects), might require more complicated design details.

Table A. 14: Attributes of 'VS16- Low Constructability'

Name	Description
Unsuitable construction methods/changes in method	Constructability level of a project might decrease due to application of obsolete, unsuitable, or wrong construction method or occurrence of frequent changes in the construction method.

Poor communication between project management and design team	Design, constructability, budget, time, and quality requirements are some important factors, which shall be considered in the selection of construction method. The most suitable construction method, which addresses a high level of constructability, can be selected through development of an effective communication and coordination systems among project management and design teams.
High level of technology complexity	Projects that require high level of innovation, aimed to meet high technological standards or possess high technical complexity in its nature (i.e. petrochemical plant, large power plants, and large-scale infrastructure projects) can be sources of project complexity. In these types of projects, incompetent designers or engineers might not cope with project complexity, which in turn might result in constructability problems.
Inappropriate project delivery method	Relation and communication paths among project participants generally are determined with the project delivery methods. A delivery method, which requires a close contractual relationship and partnering among parties, might enable an effective communication system and decrease possible constructability conflicts.
Lack of knowledge about location restrictions	Constructability level of a project might be decreased due to the some location restrictions. These restrictions can be listed as; working in a congested area, doing business in a country that requires strict rules to prevent noise and other inconvenience, unavailability of transportation facilities, limited site access and topographical restrictions.
Incomplete specifications/design standards and codes	Any errors, incompleteness of specifications or inconsistencies between clauses might cause to misleading results or conflicts. These conflicts between contractor and designer might be resulted in constructability problems.
Lack of computer generated models	Computer generated tools and software packages (i.e. 3D and 4D models), might increase the overall constructability level of a project by enabling investigation of any erroneous construction activity or construction problem at the earlier stages of the project.

Table A. 15: Attributes of 'VS17- Complexity of Construction Method'

Name	Description
Complexity of plant and equipment selection	Each construction method requires a unique method for selection of plant and equipment. Some factors, which might be considered in the selection, are; the work load to be undertaken, capabilities of the machine and equipment, transportation costs, availability of maintenance facilities, topographical conditions of the site, availability and quality of the plant.
Complexity of project	Industrial projects such as petrochemical plants, large power plants, and large-scale infrastructure projects might require specialized equipment, technological methods, or special construction methods.

Table A. 16: Attributes of 'VS18- Uncertainty of Geotechnical Investigation'

Name	Description
Inadequate/ mistakes in site investigation	Allowable bearing capacity, allowable settlement, pore pressure, and effective stress of soil are some deformation and strength parameters of soil, whose calculations are based on the site investigation results. Inadequate or wrong site investigation efforts might lead to mistakes in classification of soil, and estimation of deformation and strength parameters.
High level of site heterogeneities	Soil investigation results might not reflect overall soil classification results in case of existence of site heterogeneities.
Measurement inaccuracy and data inconsistency	Data and measurements collected during site investigation shall be accurate and consistent in order to carry out reliable design calculations.
Lack of proper sampling method	Soil sample can be obtained by either disturbed or undisturbed type. Disturbed soil can be used in some laboratory tests such as grain-size analysis, liquid and plastic limit tests, soil classification and organic content tests. Undisturbed soil samples, however, can be used in consolidation or shear strength tests.
Inadequate in-situ tests or errors in test results	Common in-situ tests are standard penetration test (SPT), cone penetration test (CPT), vane shear test, pressure meter test, field load test and unconfined compression test. These tests are sensitive to a list of factors such as method of drilling, cleaning of bottom of the hole before the test, diameter of the drill hole and location of the hammer. In order to avoid possible errors or inadequacies, these tests should be performed under appropriate conditions.
Inadequate laboratory tests	Laboratory tests are performed with the aim of identification and classification of soil, measurement of soil properties (i.e. bulk density, shear strength) and determination of soil chemical contents. Some laboratory tests are; visual examination, moisture content test, liquid, and plastic limit test and particle size distribution.
Inadequate site investigation reports	Site investigation reports should consist; general description of the site, general geology of the site location, description of soil in bore holes, results of the laboratory tests, and discussion of results indicating type of foundation, type of soil and etc.
Inappropriate method of site exploration	Site exploration can be carried out by trial pits, borings (i.e. wash or rotary borings), and heading shafts. An appropriate site exploration method should be selected with the consideration of the topography, nature of ground and cost of the method.

Table A. 17: Attributes of 'VS19- Strict Quality Requirements'

Name	Description
Strict requirements for quality training	Quality training might be required to include courses regarding basic quality management requirements, cause-effect analysis of quality problems, statistical methods analyzing quality performance, communication and interaction methods and quality cost estimation methods.

Strict requirements for quality assurance and quality control system	Quality assurance is the collection of planned and systematic actions, which are carried out to achieve expected quality performance. Quality assurance actions include development of quality standards, procedures, and systems. In addition, quality control is the implementation of quality procedures in order to plan, coordinate, and control quality assurance system.
Strict requirements for statistical methods	Statistical methods enable communication of quality problems by facilitating a common language. These methods provide project participants to identify causes and effects of quality problems as well as to make use of past records and experience to forecast possible forthcoming quality problems. Some statistical methods that can be used in these objectives are; histograms cause and effect diagrams, check sheets, graphs, control charts, and scatter diagrams.
Strict requirements for inspection, testing and information analysis	Quality inspection and testing enable to identify in what extent the current progress of the construction meet the requirements of project participants and is consistent with the project objectives. Frequent sessions to the construction site should be arranged in order to collect, analyze and store construction data as well as to improve quality performance of the work.
Strict requirements for supplier involvement	Quality performance of a project is highly associated with the involvement and competency level of suppliers and level of interaction among them. For instance, designers should prepare high quality of plans, drawings, vendors should supply high quality of equipment, and materials, subcontractors should perform high quality of work.
Strict requirements of preparing nonconformance reports	Non-conformance reports serve as a tool to detect the problem areas, take corrective measures, and prevent reoccurrence of these problems. The historical data collected during preparation of non-conformance reports, might facilitate provision of possible forthcoming quality problems.
Strict requirements for application of quality control based on foreign specification	Some foreign quality codes and specifications (i.e. Euro code) constitute generally accepted and validated laws, rules, and codes. A quality control system based on these types of specifications might increase quality control performance.
Strict requirements of achieving high degree of aesthetics	Clients might aim to achieve high degree of aesthetics with making use of luxury for some construction components. These components might are; ventilation systems, electrical systems, exterior walls, roofs, interior finishes, acoustics or illumination.
Strict requirements for company registration with ISO standards	ISO standards are series of international standards regarding product design, production, delivery, and service and testing. ISO 9000 series include quality assurance standards (i.e.ISO 9001, ISO 9002, ISO 9003) and quality management standards (i.e.ISO 9004) which guide companies in establishing and implementing quality systems.
Requirement of appointing quality management staff	Quality management staff might be required to be collaborated in order to develop a quality assurance and quality control system. Staff shall arrange frequent sessions to the construction site and perform regular inspections, testing and information analysis to detect any quality problem.

Table A. 18: Attributes of 'VS20- Strict Environmental Requirements'

Name	Description
Strict requirements for prevention of dust emissions	Some sources of dust emission are; excavation, demolition, drilling, blasting, transportation of aggregates or vehicle traffic. Some requirements to avoid dust emission might are; carrying out wet excavating and wet drilling, using static crushing or chemical breaking during blasting and carrying out wet covering of loads before transporting.
Strict requirements of ISO 14000 series certificate	ISO14000 is a series of standards, which links construction management with the environmental management. Standards guide topics such as environmental management principles, environmental systems and supporting techniques, auditing principles, labeling and environmental performance evaluation.
Strict requirements of environmental management system	Environmental management system (EMS) is a developed multi-staged system in which sources and magnitudes of possible environmental risks (i.e. risks causing pollution and hazards) and mitigation strategies are proposed. EMS includes five main stages; issuing environmental policies, planning strategies, implementation and operation of system, inspection and control of the system, and review system of management.
Strict requirements for prevention of harmful gases	Some sources of harmful gases are; operation and transportation of equipment (i.e. pile driver, crane, electric welder, and scraper) or construction methods (i.e. organic solvent electric welding or cutting). Some requirements to avoid emission of harmful gases might are; using hydraulic piling equipment, electric machines, carrying out bolt or pressure connection for electric welder, and using posing free solvent or laser cutting.
Strict requirements for prevention of noise	Demolition and operation of machines and equipment are major sources of noise. Some requirements to avoid noise might are; using hydraulic or electric alternatives of these machines, limiting equipment operation hours, using laser cutting machines, establishing noise measurement systems or providing sound isolations.
Strict requirements for prevention of wastes	Solid and liquid building material and machinery oils are some sources of wastes. Some requirements to avoid the damage of wastes might be the recovery and recycle of these wastes and material saving of machinery oil.
Strict requirement of complying with international laws about hazardous wastes	Generation, transportation, treatment, storage, disposal, emergency planning, and reporting of hazardous wastes might be required to be complied with international laws and regulations. For instance, some countries require construction firms to comply with Resource Conservation and Recovery Act (RCRA), which gives authority to EPA to control hazardous wastes.
Strict requirements for threatened or endangered species	In case of project activities have probability to affect endangered plant, animal species, or habitats, it might be required to develop mitigation strategies and prepare project specific environmental rules to minimize the impacts to these species.
Strict requirements to save historic properties	In case of project site is near a cultural or historically important site, some activities (i.e. excavation) might damage historic properties. It might be required to develop mitigation strategies and prepare project specific environmental rules to minimize the impacts to these properties.

Strict requirements of green building consideration	Green or sustainable building is the practice of creating healthier and more resource-efficient methods for construction, renovation, operation, maintenance, and demolition. Green building program elements are generally related with the energy use, water use, construction materials, waste reduction, and the indoor environment.
Strict requirements for prevention of light disturbance	Site lightening and equipment lights are some sources of light disturbance, which might disturb public or wildlife. Some requirements to avoid light disturbance might are; limiting the night shifts and work hours, and using spotlights rather than flood lamps.
Strict requirements for prevention of odors	Some sources of odors might are; materials of solvents, paints, welders, asphalts, tars and exhausts of equipment. Some requirements to avoid odors are; using solvent-free materials, prefinished materials or carrying out powder coating during painting. To prevent odors created from equipment exhaust, properly tuning engines and electric motors might be used or proper emission controls might be carried out.
Strict requirements for an environmental insurance	Environmental insurance protects project participants from cost overruns that are raised due to environmental problems. Some environmental problems are; pollution, environmental error and omissions, environmental remediation, stop loss, and unforeseen environmental actions.

Table A. 19: Attributes of 'VS21- Strict Health and Safety Requirements'

Name	Description
Strict requirements of a special health and safety training program	Health and safety training program might be required to include courses about electrical works, power supplies and lines, confined space entry, trenching, dangerous chemicals, fall protection, towers, scaffolds, platforms, blasting, fire protection, substance abuse, structural collapse, demolition, and excavations. Toolbox meetings and/or perception surveys might also be required to be held which provides a feedback from workers about the applicability and usage of the trainings. Handbooks and manuals (i.e. health and safety handbooks, tunnel safety handbooks) might be required to be provided to the staff at the beginning of the project.
Strict requirements of safety monitoring and reporting	Safety monitoring refers to the identification and evaluation of the coherence of site actions based on the safety regulations and plans. Safety documentation and reporting might be required to include work-related injuries report, diseases and dangerous occurrences regulations, accident, incident and non-conformance reports, corrective and preventive action plans, and safety checking and monitoring plans.
Strict requirements of inspecting hazardous/dangerous conditions	Daily, weekly, and monthly inspections might be required to be carried out by the safety auditors. The aim of inspections is; identifying and reporting unsafe/hazardous conditions at the construction site and/or unsafe behaviors of workers. Properly developed meetings might also be required to be arranged with the aim of discussing hazardous conditions, developing corrective actions and precautions.

Strict requirements of well-defined safety organization	A well-defined safety organization structure generally consists of safety and health management representative, construction safety steering committee, safety and environmental action committee, safety manager, safety advisor and safety supervisor. The organization structure might be required to be represented on organization charts on notice boards.
Strict requirements of having a company specific safety manual	Company specific safety manuals might be required to provide information about the local safety regulations, policies, or standards. These manuals might also denote country or company specific safety actions, which would be required to be taken at site.
Strict requirements related to plant and equipment	These requirements might be related with the operation, inspection, and maintenance procedure or operator and inspector skills. For instance, equipment (i.e. cranes, mobile plant, vehicles, and excavators) should be operated by the well-trained, competent, and work-specific experienced and over 18 years-old operators.
Strict requirements of safety signage and warnings at site	Safety signage and warning enable workers and staff to take precautions and protective actions by representing the unsafe conditions that might be resulted with a hazard or an accident.

Table A. 20: Attributes of ‘VS22- Strict Project Management Requirements’

Name	Description
Strict requirements of a complicated time management system	Time management system consist multi-staged actions in order to carry out project in schedule and complete project on or ahead of predefined finish date. These actions include; defining project activities, estimating durations, sequencing activities, determining resources, defining milestones and critical paths, and developing and controlling the schedule.
Strict requirements of a complicated cost management system	Cost management system consist multi-staged actions in order to complete project in predefined project budget and achieve cost investment objectives of project participants. These actions include; planning of resources, carrying out quantity take-off, identifying unit costs of resources, estimating total cost, controlling, reporting, and documenting the cost data.
Strict requirements of a complicated quality management system	Quality management system generally consist actions of developing quality assurance and quality control system, training workers and staff on quality, utilizing statistical methods, estimating cost of quality, and monitoring and reporting quality of progressed work.
Strict requirements of a complicated human resources management system	Human resources management involve actions of development of organizational structure, distribution of work among workers, acquisition of staff, definition of responsibilities of workers and staff, monitoring and supervising workers, training and motivating workers and staff.
Strict requirements of a risk management system	Risk management system consist actions of identification of potential risk sources, assessment of identified risks with the use of analysis tools and methodologies, development of risk response techniques in order to alter with the risk consequences, allocation of risk ownership, estimation of contingency amounts, and risk monitoring, reviewing and reporting.

Strict requirements of a health and safety management system	Health and safety management system consist actions of development of a site-specific safety plan and a safety organization structure, inspection of hazardous/ dangerous conditions, safety monitoring, documentation and reporting of safety issues, training staff about general safety instructions and precautions, and development of a personnel protection program.
Strict requirements of a procurement management system	Procurement management system consist actions of selection of appropriate tendering and procurement contract type, development of source selection criteria of procured goods and services, development of procurement strategies and methodologies, documentation of procurement process and procurement of goods sufficient in quality and quantity.
Strict requirements of a communications management system	Communication management system involves actions of development of organizational communication structure and communication plan, distribution of information and reporting the status of work tasks and progress measurements.
Strict requirements of a scope management system	Scope management system involves actions of identification of organizational requirements and verification, planning and control of project scope/ objectives.

Table A. 21: Attributes of 'VS23- Vagueness of Contract Clauses'

Name	Description
Lack of standardized contract clauses/formats	In case of the use of local contract clauses/formats instead of internationally accepted or standardized ones (with which participants might be experienced or be familiar), project participants might have difficulty to understand, follow and respond these terms and clauses.
Lack of coherence of the contract clauses to the project	Project attributes, conditions and requirements (i.e. project scope, project definition, obligations of project parties, responsible parties from risks, variations, and changes) should be defined through contractual clauses. These clauses should be coherent with each other and should be complied with overall project scope and satisfy objectives of project participants.
Poor definition of rights, obligations and risk sharing among project parties	Contract clauses should define rights and duties of each party, identify responsible participant who would bear possible cost overruns, time delays, variations, or changes, share construction risks among participants and acquire penalties for any incompetent or faulty works.
Poor definition of cost sharing schemes	Contract clauses should comprise conditions of fee agreement, fee payment method, change order, claims, bond, interest, insurance, license fees, damages/loses, expenses/royalties, reimbursements, compensation, and guaranteed maximum price of project.
Poor definition of legalized management procedures	Contract clauses should state any legalized management procedures or operations, coordination of resources and labor, and application of environmental and safety requirements. These should be applied in a way that, contract delivers all the work required to complete the project within pre-defined agreements, scope, time and cost constraints.
Poor definition of claims and dispute resolution method	Contract clauses should comprise dispute resolution methods with the aim of avoiding or minimizing unresolved claims and disputes, disruption of work, and stoppages of work. Some resolution methods are; lawsuits, litigation, arbitration, mediation, conciliation, and negotiation.

Lack of a contractual relationship structure	Contractual relationship structure among project participants (i.e. client, contractor, insurance company, suppliers) might avoid or minimize discrepancies among interpretations of clauses, contract errors, incompleteness of clauses, and conflicts among participants.

Table A. 22: Attributes of 'VS24- Contract Errors'

Name	Description
Inappropriate contractual procedure/ type of contract	Contract type (i.e. cost-reimbursable, fixed-price) should be properly selected to suit project environment and conditions, cover management of unique projects, cover rights, duties and responsibilities of project participants, and share construction risks among them with also benefiting their objectives.
Inadequate performance/quality, flaws of contract clauses	Contract clauses should respond to requirements, obligations, and liabilities of project participants with equality and comprehend project conditions and environment.
Inadequate duration of contract period	Limited time given to the contracting period is one of the causes of contract errors. Sufficient time should be allocated to the determination of contract clauses, preparation, and review of contract documents in order to avoid or minimize contract errors.
Lack of standardized contract clauses/forms	In case of the use of local contract clauses/formats instead of internationally accepted or standardized ones (with which participants might be experienced or be familiar), project participants might have difficulty to understand, follow and respond these terms and clauses.
Lack of contract documents	Contract documents should consist; contract drawings, plans, specifications, standards, bill of quantities, written contractual statements, should introduce responsibilities, obligations, and liabilities of project participants and include a legal agreement and a tender (financial offer) submitted by the contractor.

Table A. 23: Attributes of 'VS25- Technical Incompetency of Engineer'

Name	Description
Lack of experience in tendering process	Tendering process include actions of conducting feasibility study, preparing and documenting initial cost estimations, determining required technical and financial resources, preparing contract documents and developing a tender program.
Lack of experience in design process	Responsibilities of the engineer during design process include; monitoring design team, responding to queries of the team, evaluating preliminary and final design calculations and drawings, documentation of required standards and specifications.
Lack of experience in construction process	Responsibilities of the engineer during design process cover; monitoring site facilities, reviewing detailed design drawings, inspecting and testing construction operations, detecting, responding and managing possible technical problems arising at site.

Lack of experience in cost estimation	Cost estimation include action of carrying out quantity take-off, identifying unit prices of technical resources, preparing bill of quantities, developing a cost estimation technique, monitoring and reporting progress payments, controlling stock, establishing cash flows and budget.
Lack of experience in resource allocation	Resource allocation includes action of identifying the amount and type of technical resources (i.e. material, equipment, labor force, infrastructure components) and controlling, inspecting and testing the productivity and availability of these resources.
Lack of experience in scheduling	Scheduling covers actions of identifying activities that are required to complete a specific work, sequencing activities, determining duration required to complete work tasks, developing a project schedule and properly updating the progress of the project based on the actual schedule.

Table A. 24: Attributes of 'VS26- Managerial Incompetency of Engineer'

Name	Description
Lack of experience of engineer/newly graduated engineer	Managerial competency generally is achieved with the experience gained from previous projects. Newly graduated engineers might be lack of experience and dependence of project on newly graduated engineer(s) might decrease the overall competency degree of the project.
Poor coordination/communication management ability	Coordination and communication management covers the actions of; establishing communication systems within the organization, enabling information flow among project participants, and developing properly arranged meeting sessions in order to investigate and address problems.
Poor documentation and delays in approval of documents	High level of bureaucracy involved in governmental departments, high level of project complexity or tight project schedules might lead to carrying out documentation and approval procedures improperly. It is engineers' responsibility to prepare documents (i.e. architectural design and structural analysis) and to get approval of them from related departments, agencies.
Poor problem solving and change management ability	Change management covers actions of; arranging periodic sessions to address and to discuss change orders, problems, or any other scope variations, negotiating with other project participants to solve possible problems, adapting change orders to real operation, and reporting and documenting results, discussions and negotiations.
Poor control ability	Control management covers action of; arranging periodic sessions to collect progress measures, maintaining and analyzing these measures, controlling construction documents and drawings, inspecting and testing construction operations.

Table A. 25: Attributes of 'VS27- Engineer's Lack of Financial Resources'

Name	Description
Lack of a short-term finance/ financial status of the engineer	Short-term finance refers to the short-term capital to overcome immediate cash flow problem, especially when the engineering firm is newly established. Short-term capital can be used to overcome cash problems resulting from market price fluctuations, materials/ equipment purchase and staff wages especially when the progress payments for the finished product is not received yet.

Table A. 26: Attributes of 'VS28- Client Unclarity of Objectives'

Name	Description
Unclarity about project scope	Scope definition includes actions of defining objective and limitations of the project and identifying project management requirements (i.e. cost, time, quality, health, and safety). Expectations and responsibilities of each project participant should be clearly defined in order to avoid or minimize conflicts, missing statements and claims.
Unclarity about project objectives	Projects objectives are generally perceived as undertaking a project under budget, in schedule and within the expected productivity and quality. In this regard, client should be clear about his/her responsibilities and expectations and denote them to all other project participants.
Unclarity about contract terms	Contract terms should comprehend project objectives, motivate all participants to achieve these objectives, allocate risks among project participants, and clearly indicate obligations, rights, and expectations of all participants.
Unclarity about project attributes	Project size, type, budget, country, year are some attributes of a project. Clients should clearly interpret, where would the project take place, when the construction of the project would start, what type of construction would be carried out, and which parties would be take part in the project.

Table A. 27: Attributes of 'VS29- Client Level of Bureaucracy'

Name	Description
Excessive and complicated approval procedures	This attribute refers to the requirement of excessive amount of work to be carried out in order to get approval for any document by client organization. Due to high bureaucracy involved in client organization, project approval, license approval, or land acquisition might be delayed.
Slow decision-making in the client's organization	Existence of excessive amount of paperwork or existence of strict rules and regulations imposed by a fragmented client organization or a client organization comprising high bureaucracy, might lead to slowness in decision-making process with the organization.
Slow permits by client organization	Slow permits from client organization refer to the delay in approval of documents, reports, or permits from client organization. High level of bureaucracy might entail a time-consuming approval process, due to necessity of examination and control of each document.

Table A. 28: Attributes of 'VS30- Client Negative Attitude'

Name	Description
Bad reputation of the client	Bad reputation of client refers to the unfavorable image of the client organization due to exhibiting unethical or dictatorial behavior, rising excessive and redundant claims, being uncompromising, debater or iniquitous.
Difficulties to arrange meetings	Client should arrange and attend proper meetings to listen and determine requirements and expectations of project participants, to confirm reports/project data, monitor and supervise the construction process, resolve possible conflicts by achieving arrangements and establishing proper relationships.
Negative attitude towards project parties	Some indicators of negative attitude of client towards other project participants are; uncooperativeness of client, high amount of arising conflicts and legal disputes, unethical behaviors served by client to achieve highest possible level of profit, and serving adverse relationships/attitude.
Poor human resource management and leadership ability	Motivating and building up relationships with workers and staff can be achieved by; arranging interviews and meetings, encouraging them about participation to the project, setting up better communication, providing a friendly environment, avoiding blaming behavior, briefing about project conditions, listening and being open to the interaction.

Table A. 29: Attributes of 'VS31- Client Poor Staff Profile'

Name	Description
Lack of experience of technical staff	Technical requirements of client organization are; implementing proper construction, delivery, procurement and quality control methods, monitoring design process, understanding drawings and responding design team, monitoring construction site facilities, responding possible technical problems arising at construction site, detecting problems early, managing any rework.
Lack of experience of management staff	Managerial requirements of client organization are; implementing organizational behavior, developing a tendering system, allocating human and construction resources, managing and monitoring change orders, developing coordination/communication systems, allocating time and schedule, developing cost estimation techniques, and developing quality control and assurance systems.
Lack of experience of staff within the similar past projects	Project size, type, year, duration, and budget are some attributes of a project. Technical and managerial experience gained in past projects might be used to predict performance of a forthcoming project in the condition of both projects have similar attributes.
Lack of education and training of staff	Training of staff refers to the development of staff skills and experience based on their job definition with the aim of increasing the overall productivity. Therefore, employers should organize training programs, courses and pay more attention to the human resources by arranging seminars and courses, or role-playing with simulation exercises.

High number of newly-graduated staff	Managerial and technical competency generally is achieved with the experience gained from previous projects. Newly graduated engineers might be lack of experience and dependence of client organization on high number of newly graduated staff might decrease the overall competency degree of the organization.
Non-realistic organizational structure and work distribution among staff and workers	Development of a realistic organizational structure requires; examination of experiences and abilities of each employee, and identification of their job specifications and roles. With a well-structured organizational behavior, each employee can work in areas where they possess technical and/or managerial competency, which in turn increases the overall productivity of a project.

Table A. 30: Attributes of 'VS32- Client Unavailability of Financial Resources'

Name	Description
Lack of a long-term finance	Long-term finance refers to a capital that is required for five to ten years to do business or carry out construction projects. Long-term finance might be used to purchase construction land, building, or construction technical resources. Some sources of long-term finance are; retained profits, bank loans, shares, government grants, or debentures.
Lack of a short-term finance	Short-term finance refers to the short-term capital to overcome immediate cash flow problems, especially when the firm is newly- established. Short-term capital might be used to purchase materials, hire plant, and pay labor or subcontractor wages. Some sources of short term-finance are; clearing bank overdraft and loan facility, provision for taxation, value added tax (VAT), market instruments such as bonds, creditors, and internal transfer.
Unavailability of funding source from the host government	The host country government can finance client (should be a construction company or an individual) directly or indirectly. Host country government can loan funds to the client company (direct funding) or provide financing assistance through tax relief (i.e. tax holidays) or minimize custom duties (indirect funding).
Unavailability of funding source from lenders or banks	In large projects financial sources might be provided by a lender in the form of a commercial or a development bank (i.e. World Bank, Asian Development Bank), a pension fund, an insurance company, an export credit agency or an association (i.e. International Monetary Fund). Client can also make agreements with a guarantors (i.e. a sponsor or a third party), institutional investors, utility subsidiaries, vendors, and contractors to provide financial resources.
Lack of financial risk identification and mitigation strategies	Financial risks can be grouped as; interest, payback, loan, equity, dividends and currencies risks. While interest risks are related with the type of rate, changes, and fluctuations in interest rate, payback risks are the ones that are about; loan period, fixed payments, cash flow milestones, discount rates, rate of return, scheduling of payments. Loan risks include; type and source of loan, availability of loan, cost of servicing loan, debt/equity ratio, holding period, existing debt, and covenants. Equity risks are related with the; institutional support, take-up of shares, type of equity offered, while dividends are with the time and amounts of dividend payments. Currencies risks include; currencies of loan, ratio of local/base currencies, mixed currencies.

Unavailability of cash money due to other ongoing projects	In case client organization is carrying out more than one ongoing project, it might be difficult to arrange financial sources and provide cash money to the several contractors. In order to alter with the shortage of financial sources, organization should develop an appropriate financial plan prior to the assigning a project.
Lack of contingency funds for unexpected situations	Sufficient amount of contingency should be estimated and stated in the contract in order to alter with cost overruns that are raised due to unexpected situations. Unexpected situations might are; price escalation of materials and equipment, cost variations in labor, currency and interest rate fluctuations.
Lack of an appropriate financial plan	Financial plan might be developed with the provision of budget incomes and outcomes, identification of financial sources and abilities of client organization, allocation of incomes and savings to the outcomes and expenses. A financial plan should be prepared prior to the implementation of a project with the collaboration of a cost estimator and client organization.
Lack of financial guarantees from project sponsor	Tender guarantee, performance guarantee, and completion guarantee are financial guarantees that might be requested from the project sponsor. Tender guarantee is often requested to eliminate sponsors who do not have sufficient financial resources, whereas performance guarantee is requested to ensure the payment of a financial penalty in condition of sponsor is failed. Completion guarantee is required to ensure the project is completed on time as well as assure revenue can be generated.

Table A. 31: Attributes of 'VS33- Client Technical Incompetency'

Name	Description
Lack of experience in preparation of a project plan	Some issues, which should be included in a project plan, are; political and economic structure of the host government, environmental, health and safety requirements, design and quality standards and specifications, contractor and subcontractor selection methodologies, and methodologies to implement project management functions.
Lack of experience in conducting project feasibility study	Feasibility studies enable client to decide on strengths, weaknesses, opportunities, risks of the project, achievability of the project objectives, and resources that are required to carry out project. Some studies, which should be carried out during feasibility stage are; financial status of client, technical and managerial competency of client organization and its contractors, availability of construction resources and attributes of host country.
Poor cost management ability	Cost management ability of client organization involve, implementation of cost estimation techniques and cash flows, development of cost reporting systems, VAT and taxation payment system, identification of financial status, development of investment appraisal, control and evaluation of stock.
Lack of experience in involvement in construction stage	Involvement in construction stage, enable client organization to monitor construction site facilities, respond engineers and contractors to the possible technical problems arising at construction site, as well as detect problems early and if they would occur, manage the rework process.

Lack of experience in documentation and approval of documents	Client should develop a technically competent team to prepare required documents, and to approve and revise design documents, shop drawings received from designer, and sample materials and progress reports received from field engineer.
Lack of experience in controlling	Client organization should be able to control design changes, and verify the compatibility of design with the regulations and standards. In addition, client organization might establish a quality assurance and control schema as well as employ procurement policies, require a cost reporting system, develop a controlling team within the organization.

Table A. 32: Attributes of 'VS34- Client Poor Managerial/ Organizational Ability'

Name	Description
Poor resource management ability	Resource management include actions of identifying the amount and type of technical resources (i.e. material, equipment, labor force, infrastructure components), as well as allocating, directing, controlling, inspecting, and testing quality and productivity of these resources.
Slowness in decision making process, giving instructions	Slowness in understanding and responding the designers' or engineers' queries, or taking actions to the change orders or resolving any possible conflicts are some indicators of managerial incompetency of client organization.
Poor coordination/communication management ability	Coordination and communication management covers actions such as; establishing communication systems within the organization, enabling information flow among project participants, and developing properly arranged meeting sessions in order to investigate and address potential problems.
Improper selection system for contractors	Client organization should define a contractor selection methodology, identify organization requirements and priorities, and based on these requirements and selection methodology, should select the most appropriate contractor company.
Lack of early and continuous involvement to the project	Client organization should involve project in earlier stages, attend properly arranged meetings, and monitor construction progress. The early and continuous involvement of client organization increases achievability of project management functions (i.e. time overruns might be minimized while getting permits from governmental departments by interaction of client organization with the departments).
Improper selection of project location, type	Client organization should have ability to select the most appropriate project location and project type based on the project objectives. The organization should also hand over the project site to the contractor in order to avoid possible delays that are related with the setting up the site.
Poor problem solving and change management ability	Change management covers actions of; arranging periodic sessions to address and discuss change orders, problems, or variations, negotiating with the project participants to solve these problems, adapting change orders to real operation, reporting and documenting results of the discussions and negotiations.

Poor human resource management and leadership ability	Human resources management involve actions of; developing an organizational structure, distributing work among workers, appointing staff, defining responsibilities of workers and staff, monitoring, supervising, training, motivating workers and staff. Some leadership abilities of client might are; developing interviews with staff to understand their needs, encouraging them to participate, setting up better communication, providing a friendly environment, not blaming, listening and being open to the interaction.
Poor monitoring and supervising staff/workers	Client organization should arrange proper sessions to monitor and supervise staff and workers. These sessions might create an opportunity to client organization to identify potential risk factors that might decrease productivity of staff or workers.
Poor relations with client and related governmental departments	Client organization should establish appropriate relations with governmental agencies and departments in order to get approval for land acquisition, permission for development and commencement of construction, and permissions for occupation of properties. Organization should also establish relations with trade unions, environmental protection groups, and public authorities of the host country.

Table A. 33: Attributes of 'VS35- Poor Site Supervision'

Name	Description
Lack of a system for monitoring and supervising staff/workers	A monitoring and a supervision system should be developed to identify potential risks that might have an adverse effect on project objectives. Within the context of the system, properly arranged site visit sessions should be collaborated to identify potential problems related to the site facilities.
Technical incompetency	Client or contractor organization should possess technical competency in order to monitor construction site facilities, respond project participants' queries, approve design documents/ shop drawings, discuss technical problems, detect potential problems, and manage possible reworks or change orders.
Poor procurement and quality control ability	A procurement and quality control system should be developed to allocate and schedule resources, carry out quality assurance and quality control, control technical design, test construction equipment and materials, monitor and supervise site facilities.
Lack of design and construction check	Regular design checks should be performed in order to satisfy the compatibility of design methodology with the method of construction. In addition, regular site visit sessions should be arranged to avoid possible design errors at construction site and to check progress of the project.

Table A. 34: Attributes of 'VS36- Lack of Site Facilities'

Name	Description
Lack of transportation systems	Transportation facilities should be provided to enable both inside and outside site access. Roads, traffic routes, trailers, and traffic signs are some components of transportation facilities.

Lack of accommodation facilities	Accommodation facilities include accommodation buildings, welfare facilities, meal rooms, drinking water, and eating facilities, resting areas, toilets, washing and shower centers and change rooms.
Lack of storage places	Storage places and containers should be available at the construction site to enable storing and handling materials and equipment.
Lack of administration buildings	Administration buildings should be facilitated to provide a platform to the project managers in order to facilitate project management functions (i.e. time, cost, and quality management).
Lack of temporary facilities	Temporary facilities should be constructed by taking into consideration of specific needs of site personnel, number of working shifts, job location, safety, and cost requirements. These facilities might include electricity, water and gas supply, heating units, compressed air service, ventilation systems.

Table A. 35: Attributes of 'VS37- Contractor's Lack of Experience in Similar Projects'

Name	Description
Lack of experience in similar type of projects	Experience gained in similar type of projects assist contractor in forecasting risks specific to that project type, determining special design requirements (i.e. specialized design techniques), determining construction techniques (i.e. specialized construction method), identifying required project activities and their attributes (i.e. durations, resources) and conducting feasibility study in a more easy way.
Lack of experience in projects having similar size	Contractor might benefit from their experience while determining the required type and amount of the financial sources, expected profit of the project, preparing financial plan, developing cost control and checking system, identifying required cost data, and making direct costs, indirect costs, and contingency amount approximations.
Lack of experience in projects having similar location	Experience gained in projects having similar locations enable contractor to acquire knowledge about host country attributes. These attributes are; economic conditions, governmental structure, legal framework (i.e. laws, regulations, courts), level of bureaucracy, physical conditions (i.e. climate, geographic and geotechnical conditions), availability of construction resources of the host country.
Lack of experience in projects having similar construction technology/method	Experience in projects carried out with similar construction technology/method enable contractor to determine material and equipment requirements (i.e. type and amount), technological device requirements (i.e. specialized devices), labor requirements (i.e. specialized skills), and any other special requirements of the technique/method.

Table A. 36: Attributes of 'VS38- Contractor's Lack of Experience in Country'

Name	Description
Lack of knowledge about general information	General information of the country covers; its capital, major cities, location, topography, currency, exchange rates, population and language, religion, ethnic groups, climate, coastline, time difference, calendar, national days, holidays, measurement system, international dealing code.

Lack of knowledge about governmental structure and political conditions	Some governmental and political structure attributes of a country are; its government type, regime, provinces, capitals, governors, government ministries, administrative divisions, constitutions, legal and judicial structure, elections, law and affiliations.
Lack of knowledge about economic conditions	Some economic attributes of a country are; its gross domestic product (GDP), current account balance, current account balance in percent of GDP, export values, import values, inflation rate, interest rate, banking system.
Lack of knowledge about business and financial conditions	Some business and financial attributes of a country are; work permit requirements for foreign workers, employment contract and a local partner requirement, visas, taxation, depreciations, custom duties, custom taxes for vehicles, insurance, residency, construction license requirements, investment incentives, opening a bank account, import standards, and procedures, if exits prohibited import products.
Lack of knowledge about environmental, health and safety regulations	Having knowledge about a regulations of a country might require a research/an experience about its environmental, health and safety legislations and laws as well as, if exits, any special requirements.
Lack of knowledge about market conditions	Some attributes of market conditions of a country are; existence of supermarket chains, international food chains, hotels, transportation and infrastructure facilities, as well as availability of local construction labor, construction material, machinery and equipment, existence of water and electricity supply, and housing opportunities.
Lack of knowledge about the legal framework	Some attributes of legal framework of a country are; its judiciary (i.e. its independence), legal system (i.e. its effectiveness), property rights and law (i.e. sufficient laws for joint ventures) perception.

Table A. 37: Attributes of 'VS39- Contractor's Lack of Experience in Project Delivery System'

Name	Description
Lack of knowledge about responsibility sharing between parties	Project delivery systems specify the responsibilities of clients, designers, contractors, and engineers as well as allocate construction risks among them. Participants should select the best method with the consideration of customer and client needs, time and budget constraints, design completeness, project complexity, competencies and experiences of participants.
Lack of knowledge about the contracting system of selected PDS	Each project delivery system requires different contracting methodology among project participants. For instance, client organization should conduct separate contracts with designer and contractor in design-bid-build system, whereas in design-build system, with a single entity that is the collaboration of a designer and contractor organization.
Lack of knowledge about the potential risks of selected PDS	Each project delivery system evolves different risks for construction parties. For instance, the system of design-bid-build might have an adverse effect on all project participants by hindering communication between participants, which in turn might result in conflicts. However, in design-build system, major risk is for the client. In this system, client have significantly less control while compared with other delivery methods, therefore might exposed to no coinciding expectations and the final product.

Table A. 38: Attributes of 'VS40- Contractor's Lack of Experience with Client'

Name	Description
Lack of knowledge about attributes and past performance of client	Some attributes and indicators of past performance of client organization are; its company age, familiarity with regulating authorities, familiarity with local working culture, health and safety record, quality assurance and performance record, past failure, type and scale of the project completed in past years.
Lack of knowledge about attitude and ethics of client	Some negative attitudes served by client organization might are; uncooperativeness, unethical behaviors to achieve highest possible level of profit and adverse relationships with other project participants.
Lack of knowledge about financial resources of the client	Some attributes of financial status/capability of client organization are; its current commitments, authorized and paid-up capital, working capital, current and fixed assets, net worth, turnover, profit generating ability, liquidity status and capital structure.
Lack of knowledge about managerial skills of the client	Some managerial responsibilities of the client are; supplying construction resources to the contactor, coordinating project participants, giving instructions and fast decision making, developing an organizational structure, monitoring project tasks, establishing relationships with the host country governmental departments.
Lack of knowledge about technical competency of the client	Some technical responsibilities of the client are; defining project scope, developing an appropriate time and cost management system, developing a well-structured quality control and assurance system, as well as possessing research and development capability and technical capability (i.e. manpower, machinery) to support the project.
Lack of knowledge about tendering/ bidding behavior	Some attributes of tendering/bidding behavior of client organization are; its tendering approach (i.e. public tendering), tendering ethics (i.e. whether with justice and clarity), bid evaluation behavior (i.e. whether scientific, rational, objective and reasonable), contractor selection behavior (i.e. whether selection of appropriate and experienced contractors).

Table A. 39: Attributes of 'VS41- Contractor's Lack of Financial Resources'

Name	Description
Lack of a short-term finance	Short-term finance refers to the short-term capital to overcome immediate cash flow problems, especially when the firm is newly- established. Short-term capital might be used to purchase materials, hire plant, and pay labor or subcontractor wages. Some sources of short term-finance are; clearing bank overdraft and loan facility, provision for taxation, value added tax (VAT), market instruments such as bonds, creditors, and internal transfer.
Lack of a contract between client and contractor	Contract should include a properly structured financial loan package and a term sheet or the statement of agreements between the client and the contractor. Term sheets and contracts should define the rights and obligations of each party, describe default conditions and remedies, and serve as the bid document for accessing capital markets.

Unavailability of funding source from lenders or banks	In large projects financial sources might be provided by a lender in the form of a commercial or a development bank (i.e. World Bank, Asian Development Bank), a pension fund, an insurance company, an export credit agency or an association (i.e. International Monetary Fund). Client can also make agreements with a guarantors (i.e. a sponsor or a third party), institutional investors, utility subsidiaries, and vendors and contractors to provide project financial resources.
Lack of financial risk identification and mitigation strategies	Financial risks can be grouped as; interest, payback, loan, equity, dividends and currencies risks. While interest risks are related with the type of rate, changes and fluctuations in interest rate, payback risks are the ones that are about; loan period, fixed payments, cash flow milestones, discount rates, rate of return, scheduling of payments. Loan risks include; type and source of loan, availability of loan, cost of servicing loan, debt/equity ratio, holding period, existing debt, and covenants. Equity risks are related with the; institutional support, take-up of shares, type of equity offered, while dividends are with the time and amounts of dividend payments. Currencies risks include; currencies of loan, ratio of local/base currencies, mixed currencies.
Lack of contingency funds for unexpected situations	Sufficient amount of contingency should be estimated and stated in the contract in order to alter with cost overruns that are raised due to unexpected situations. Unexpected situations might are; price escalation of materials and equipment, cost variations in labor, currency and interest rate fluctuations.
Lack of an appropriate financial plans	Financial plans can be developed with the provision of budget incomes and outcomes, identification of financial sources and abilities of client organization, allocation of incomes and savings to the outcomes and expenses. A financial plan should be prepared prior to the implementation of a project with the collaboration of a cost estimator and client organization.

Table A. 40: Attributes of 'VS42- Contractor's Lack of Technical Resources'

Name	Description
Lack of raw materials	Some construction raw materials are; steel, cement, aggregate, water, quicklime, asphalt, electric blasting circuits, bituminous material, concrete masonry units, brick, mortar, and gas oil.
Lack of equipment	Some construction equipment are; excavator, crane shovel, dragline, crane, dozer, loader, scraper, truck and wagon, compaction equipment, drilling equipment, rock crusher, concrete batching and mixing equipment, compressor, pile driver and spare parts of all required equipment.
Lack of labor	Lack of labor refers to the unavailability or incompetency of construction labor that are responsible from construction site works.
Lack of subcontractors	Lack of subcontractors refers to the unavailability or incompetency of subcontractors who are responsible from installation of electrical, plumbing, heating, and ventilation systems.

Lack of utilities	Lack of utilities refers to inexistence or unavailability of transportation facilities (i.e. road networks, airports, highways, railways and sea ports), communication facilities (i.e. telephone mainlines, mobile telephone services and internet penetration), and power facilitates (i.e. power generation, electricity, gas energy and heating system).
Lack of temporary facilities	Temporary facilities should be constructed by taking into consideration of specific needs of site personnel, number of working shifts, job location, safety, and cost requirements. These facilities might include electricity, water and gas supply, heating units, compressed air service, ventilation systems.

Table A. 41: Attributes of 'VS43- Contractor's Lack of Staff'

Name	Description
Lack of a technical staff	Technical staffs are; civil engineers, architects, mechanical engineers and electrical engineers, who are responsible from design and construction works, implementation of heating, ventilation, electrical and plumbing systems.
Lack of cost estimator/ planner	Project planner should define project activities and their attributes (i.e. durations, resources, relations), carry out project scheduling by sequencing activities, and update the schedule based on the actual work progress. Cost estimator should identify resources based on the predefined project activities, collect unit prices of each resource item, take bill of quantities, and estimate overall cost prices.
Lack of field (site) manager	Field (site) manager should install, test and support construction site activities, construction process and products. A field manager should plan and define work tasks, determine required resources, assist in directing and coordinating these resources, monitor work progress, evaluate possible errors and changes.
Lack of procurement engineer	Procurement engineer is responsible from selection of appropriate tendering and procurement type, preparation of a procurement contract, selection of goods and services, determination of source selection criteria, development of procurement methodology, procurement of equipment and materials, and monitoring and controlling the procurement process.
Lack of contract administrator	Contract administrator is responsible from preparation and control of progress reports and payments, changes, delays, approvals, permits, potential claims, disputes and contract termination. Contract administrator should have ability to charge official paperwork, keep track of changes, complaints, legal aspects, cost reports, monthly reports, billings, and questions.
Lack of project controller	Project control is responsible from keeping daily account of progress, cost variances, labor charges, capital equipment status and project supplies with the involvement of other project participants.
Lack of a quality manager	A quality manager (QA/QC manager) should develop a quality system, arrange quality-training courses for staff, and monitor performance of quality assurance system. It is quality managers' responsibility to ensure compliance with ISO9001 through internal quality audits, and to ensure compatibility of subcontractors' quality assurance system with the contract requirements.

Lack of safety engineer	Safety engineers' responsibilities cover; providing and maintaining safety-related equipment (i.e. first aid kids, hard hats) and other personal protection equipment, arranging regular site inspections with the aim of testing tools and equipment, and ensuring site personnel follow the safety rules, reporting project manager all unsafe practices, educating field personnel about safety, and if necessary developing a company and project-specific safety policies.

Table A. 42: Attributes of 'VS44- Poor Project Scope Management of the Contractor'

Name	Description
Poor definition of organization requirements	Organization requirements can be categorized as project requirements and product requirements. Project requirements refer to the business, project management, delivery requirements, etc. However, product requirements related with the technical, security, product requirements, etc. Requirements should be interpreted with the quantified, comprehended, and documented clauses in order to reflect needs and expectations of all project participants.
Lack of tools and techniques	In order to define project scope, firstly requirements of project participants should be identified. Some tools and techniques, which can be used during the identification of these requirements, are; interviews, focus groups, facilitated workshops, group creativity techniques, group decision-making techniques, questionnaire and surveys, observations and prototypes.
Poor project scope definition	Scope definition refers to the development of a detailed project and product description. The project scope statement describes deliverables of a project and works that should be carried out to achieve those deliverables. Project scope definition and statement should include, project scope description, product acceptance criteria, project deliverables, project exclusions, project constraints, risk, and assumptions.
Poor scope verification	Scope verification refers to the formalization of the appropriateness and acceptance of the completed deliverables of a project. It includes actions of; reviewing deliverables to confirm that those deliverables were carried out satisfactorily with incorporation of a customer or a sponsor, and obtaining formal acceptance of deliverables by the customer or sponsor.
Poor scope control	Scope control refers to the actions of monitoring and reviewing the status of the project scope, and managing changes and updates based on scope baseline. Project scope control enable to be ensured that all required changes and recommended corrective or preventive actions are performed based on the predefined requirements.

Table A. 43: Attributes of 'VS45- Poor Project Time Management of the Contractor'

Name	Description
Poor definition of activities	Definition of activities refers to the identification of actions that are required to complete the specified construction work. Activities should be defined with their attributes such as activity ID, WBS ID, activity name, activity description, and as well as their predecessor and successor activities. Some tools and techniques to

	define project activities are; decomposition, rolling wave planning, templates and expert judgment.
Poor estimation of activity relationships and durations	Estimation of activity relationships and durations refers to the identification of the sequence of each activity and estimation of the work periods required to finish the specified work item. Activities should be sequenced with respect to their logical relationships (i.e. as a predecessor or a successor). Most common method, which can be used to relate activities, is the Critical Path Methodology (CPM).
Poor estimation of activity resources	This attribute refers to the process of defining the type and amount of construction resources (i.e. material, labor, equipment) which are required to carry out construction works. Estimation of activity resources might be used to establish resource calendars and resource constraints on schedule. Some tools and techniques that might be used to define activity resources are; expert judgment, alternative analysis, published estimating data, bottom-up estimating and project management software's.
Lack of development and control of schedule	This attribute refers to the process of defining and monitoring the activity sequences, durations, resources in order to corporate project schedule and updating the schedule based on the actual progress. Some tools and techniques, which can be used to develop a project schedule and corporate schedule updates, are; schedule network analysis, critical path method, critical chain method, resource leveling, what-if scenario analysis, and scheduling tools such as MS Office or Primavera.
Poor judgment and experience of staff	Time manager or scheduler should have ability to develop a project schedule based on the predefined activities and their logical relationships. He/she should also monitor and update the schedule based on the project progress, and to develop action plans/strategies in order to mitigate with possible causative factors of time overruns.
Unrealistic contract duration	Tight and unrealistic project duration might cause time delays especially in cases of occurrence of unexpected events or adverse conditions. Therefore, contractor organization should prepare a practical schedule that allows sufficient but not redundant time to accommodate all design and construction activities.

Table A. 44: Attributes of 'VS46- Poor Project Cost Management of the Contractor'

Name	Description
Lack of experience of the cost estimator	A cost estimator should have ability to collect unit prices of construction resources (i.e. material, equipment), take bill of quantities, and estimate overall cost of the project with the predefined cost estimation technique.
Lack of financial control and check, cost reporting and documentation system	The overall aim of the financial control is; allocating financial sources, detecting possible cost related errors, and avoiding possible cost overruns. Financial control includes control of direct costs (i.e. material, equipment) and indirect costs. A cost manager should manage record keeping, prepare invoices in detail, report cost documentation among project participants.
Wrong or rigid method of cost estimation	A cost estimation method should be appropriate to cover all cost items of a project in order to ensure that all items are identified and interpreted. In addition, selected method should be flexible and not rigid in order to allocate any changes.
Inaccurate cost estimation	Contractor company should have ability to estimate and monitor income sources (i.e. progress payments) and outcomes (i.e. direct and indirect costs) of a project. Income and outcome projections should be performed accurately in order to avoid unrealistic cost estimations and to achieve cost benefit goal.

Lack of an appropriate financial plans	Financial plan can be developed with the provision of budget incomes and outcomes, identification of financial sources and abilities of client organization, allocation of incomes and savings to the outcomes and expenses. A financial plan should be prepared prior to the implementation of a project with the collaboration of a cost estimator and client organization.
Inaccurate quantity take-off	Generally, cost estimation is carried out by quantity take-off data and unit prices of the construction resources. Wrong or missing quantity take off measures might lead to unrealistic final cost amounts of a project.

Table A. 45: Attributes of 'VS47- Poor Project Quality Management of the Contractor'

Name	Description
Lack of quality training	Quality performance of a project can be improved by arranging training courses to the construction site and field office staff. The training program might cover courses about basic quality management requirements, cause-effect analysis, statistical methods, communication and interaction methods, and cost of quality estimation methods.
Poor quality assurance and quality control system	Quality assurance is the collection of planned and systematic actions, which are carried out to achieve expected quality performance. Quality assurance actions include development of quality standards, procedures, and system. In addition, quality control is the implementation of quality procedures in order to plan, coordinate, and control quality assurance system.
Poor team work	Joint teams and teamwork among project participants (i.e. engineers, contractor, and client) might establish common goals and expectations, which improve the quality performance of a project as well as increase customer satisfaction.
Lack of statistical data and utilization of statistical methods	Statistical methods enable communication of quality problems by facilitating a common language. These methods provide participants to identify causes and effects of quality problems as well as to make use of past records and experience to visualize possible forthcoming quality problems. Some statistical methods are; histograms, cause and effect diagrams, check sheets, graphs, control charts, scatter diagrams.
Poor supplier involvement	Quality performance of a project is highly associated with the involvement and competency level of suppliers and the level of interaction among them. For instance, designers should prepare high quality of plans, drawings, vendors should supply high quality of equipment, and materials, subcontractors should perform high quality of work.
Poor cost of quality measurement	Prevention cost, appraisal cost and deviation costs are some kinds of quality costs, which provide quality improvement and quality management. Prevention costs are costs used in activities that avoid deviations and errors. Appraisal cost is used in confirmation of activities, products, or processes. Deviation costs are costs occurred due to failing to meeting the requirements and objectives, and resulting in rework, error, failure of work.

Lack of company registration with ISO standards	ISO standards are series of international standards regarding product design, production, delivery, and service and testing. ISO 9000 series include quality assurance standards (i.e.ISO 9001, ISO 9002, ISO 9003) and quality management standards (i.e.ISO 9004) which guide companies while establishing and implementing quality systems.

Table A. 46: Attributes of 'VS48- Poor Human Resources Management of the Contractor'

Name	Description
Non-realistic organizational structure and work distribution among staff and workers	Development of a realistic organizational structure requires; examination of experiences and abilities of each employee, and identification of their job specifications and roles. With a well-structured organizational behavior, each employee can work in areas where they possess technical and/or managerial competency, which in turn increases the overall productivity of a project.
Poor monitoring and supervising staff/workers	Contractor should arrange proper sessions to monitor and supervise staff and workers. These sessions might create an opportunity to the contractor while identifying potential risk factors that might decrease productivity of staff and workers, or quality of the project.
Lack of providing career development to workers and staff	The human resources manager of a contractor company should learn the experience and working areas of staff and workers, as well as examine the personality of each individual. By building up relationships with staff and workers, contractor company might meet with their objectives, expectations and create them more appropriate career opportunities.
Poor motivating and building up relationships with staff and workers	Motivating and building up relationships with workers and staff might be achieved by; arranging interviews and meetings, encouraging them about participation to the project, setting up better communication, providing a friendly environment, not blaming, briefing about project conditions, listening and being open to the interaction.
Lack of education and training on human resources	Training of staff refers to the development of staff skills and experience based on their job definition with the aim of increasing the overall productivity. Therefore, employers should organize training programs, courses and pay more attention to human resources by arranging seminars and courses, or role-playing with simulation exercises.

Table A. 47: Attributes of 'VS49- Poor Communications Management of the Contractor'

Name	Description
Poor communication and coordination skills of manager	Communication and coordination skills of a manager covers; listening and questioning project conditions, confirming information, educating and directing staff, setting project expectations, managing and negotiating conflicts to achieve agreements, establishing relationships with staff, and setting and coordinating information flow among project participants.

Poor organizational communication structure	Organizational communication structure divides communication styles into four folds; organization wide, department, team and individual communication. While organization wide communication involves all employees, department communication specifies it into one department or unit. Team communication should be set within one cohesive team or group where individual communication is specific to only one employee.
Poor communication plan	Communication plans enable managers to respond, "who needs what information", "when they will need it", "how it will be given to them", and "by whom". It is crucial to provide right information, to right person at the right time. An appropriate communication plan might avoid possible conflicts, missing information statements, delays of information flow, and distribution of information to a wrong participant.
Poor information distribution	Information distribution refers to the making available of required information and tasks for each project participant.
Poor performance reporting	Reporting system refers to the collection and distribution of information (i.e. status report of each task, progress measurements of construction items) and announcement of future tasks and implementation of mitigation strategies through the reports.

Table A. 48: Attributes of 'VS50- Poor Risk Management of the Contractor'

Name	Description
Lack of risk identification system	Risk identification refers to the determination of all crucial activities within a project and action of identifying and listing all risks related with these activities. Risk identification generally, performed in a systematic manner in which risks are hierarchically categorized and defined under related project goals, parties etc.
Lack of risk assessment system	Risk assessment refers to the estimation and measurement of risk effects on project goals (i.e. cost, time) by assigning impact and probability values to each risk. Some risk assessments methods are; questionnaires, scenario analysis, risk assessment workshops, industry benchmarking and brainstorming, subjective probability, sensitivity analysis, Monte Carlo simulation, and decision analysis.
Lack of risk response system	Risk response refers to the avoidance or reduction, transfer or retention of risks in terms of contract clauses. Risks can be avoided or reduced by redefining work and project scope, developing different construction methods or redesigning project. Risks can be transferred by risk sharing among project participants or transferred to an insurance company.
Lack of risk ownership allocation	Risk allocation should be performed among project participants to avoid risk effects and it refers to the statements such as "who is carrying which risks", "which party is responsible from risk consequences". Risks can be allocated by risk retention, risk transfer, risk reduction, and risk avoidance. Risk sharing should be incorporated in partnership agreements/contracts based on the experiences and skills of project participants. It refers to the statements such as "which party best controls risks and risk consequences if they would occur", "which party can best avoid risks before it would happen"

Lack of monitoring and reviewing risks	Risk monitoring refers to actions of; identifying and checking scale of risks, and examining how they are being managed. A clear monitoring approach might avoid confusion among participants by minimizing large volumes of risk information.
Lack of contingency planning	Contractor company should carry out contingency planning in terms of contract clauses in order to resist possible cost overruns. Contingency amounts can vary from project to project and they should be sufficient in amount (generally a predefined percentage of contract amount) to protect contractors from risks and cover their additional costs.
Lack of risk training and education	The aim of risk training and education is to build a risk aware culture within an organization. These trainings can be performed with inviting risk managers to the top strategy meetings, or providing risk management courses or workshops.

Table A. 49: Attributes of 'VS51- Poor Procurement Management of the Contractor'

Name	Description
Poor selection of appropriate tendering type	Contractors should select the most suitable tendering type (i.e. competitive tendering, direct negotiation) based on their primary goals and requirements. For instance, competitive tendering is a more transparent way and provides a chance to select the most appropriate contractor who is able to perform the required task, but it might take considerable time due to attendance of several contractors/subcontractors. In case tendering duration is tight, direct negotiation can be more suitable a tendering option.
Poor selection of appropriate procurement contract type	Risk sharing between the buyer and seller is determined with the contract type (i.e. fixed price and cost reimbursement). Fixed price contracts (i.e. firm fixed price contracts, fixed price incentive fee contracts) is a more common type of contracts and consist defining a fixed total price for a defined product and service. Although it provides clients to evaluate bids in a more accurate manner, it is more vulnerable to change order risks, which can result in time and cost overruns. Opposite to the fixed price payments, in cost reimbursable (i.e. cost and fixed fee contracts, cost plus incentive fee contracts), all costs of the job, except financial risks for the contractor, would be paid to contractors by client. This contract types consists payments to the seller for the completed work and plus a profit fee.
Lack of a procurement contract	Procurement contract is a mutually binding legal agreement between the buyer and seller. While buyer obligates to provide specified goods, services and products, buyer obligates to compensate the seller. Procurement contracts can include, statement of work or deliverables, roles and responsibilities, pricing, payment terms, delivery place, inspection and acceptance criteria, warranty, limitation of liability, fees and retain age, penalties, incentives, insurance, and performance bonds, export licenses, schedule and monitor delivery dates, transportation arrangements invoices and administration of accounting records.

Lack of a source selection criteria	Source selection criteria can be included in the procurement documents and used to rate seller proposals. Some selection criteria are; technical capability, risk management approach, technical approach, warranty, financial capability, production capability and interest, past performance of sellers.
Poor procurement methodology	Procurement process covers actions of; obtaining responses of sellers, selecting the most appropriate seller and awarding a contract. In this process, buyers receive bids, tenders, or proposals and select the most appropriate seller who is qualified and skilled to perform the required work and provide equipment or materials. Some procurement tools and techniques are; bidder conferences, proposal evaluation techniques, independent estimates, expert judgment, advertising, internet search and procurement negotiations.
Poor procurement of equipment	Poor procurement of equipment refers to the procurement of equipment under the required amount that was specified in contract documents, procurement of equipment that is low in productivity or totally not procures equipment or their spare parts. Some equipment that might be procured in a construction project are; excavators, crane shovels, draglines, cranes, dozers, loaders, scrapers, trucks and wagons, compaction equipment.
Poor procurement of materials	Poor procurement of materials refers to the procurement of materials under the required amount that was specified in contract documents, procure materials that are low in quality or totally not procure materials. Some materials, which might be procured in a construction project are; steels, cement, aggregates, water, quicklime, asphalt, electric blasting circuits, bituminous materials, concrete masonry units.
Poor procurement of labor	Poor procurement of labor refers to the hire of labor under the required amount that was specified in contract documents, hire labor that are low in productivity or totally not hire labors.
Poor procurement of subcontractors	Poor procurement of subcontractors refers to hire subcontractors under the required amount that was specified in contract documents, hire subcontractors that are low in productivity or do not possess technical and managerial competency or totally not hire subcontractors. Some construction works, which might be under the responsibility of a subcontractor are; installation of electrical, plumbing, heating and ventilation systems.

APPENDIX B

This chapter presents findings of the fourth chapter of this study. As it was announced in the fourth chapter, this chapter gives previous project cases that were collected from partner firm experts and stored in the lessons learned database. From Figure B.1 to Figure B. 32, these cases are presented as in the form of they stored within the database.

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
1	50 months	2002	Turkey	150.000.000 €	Hydro Electrical Power Plant

Case Information	
Case ID	**Case Name**
1.1	Occurrence of landslides

Case Description
After a while start of the project, landslides were occurred that caused blockages on the main road. This road is the only road that give access to the construction site. Thus, road could not serve transportation facilities for the supply of construction material and equipment to the site, until the blockages on the road were removed. Unavailability of construction material and equipment lead to stop construction works, and to wait a considerable time till main access road could be reused. Although this region is known as being vulnerable to the harsh rainy weather conditions that may lead to landslides, this was the first project of the contractor company that was carried out in this region, thereby they could not forecast the risk of landslides and consequently did not take any precautions. As a result, company had to wait a considerable time to continue to the construction activities. Unexpected idle times lead to delay of some construction activities and increased overhead costs related with these activities. Thus, contractor company requested for time extension and consequent compensation for additional costs.

Case Summary			
Vulnerability Factor	**Vulnerability Source**	**Rating**	**Consequence**
Unexpected Events	Natural Catastrophes	4	Interruption
Adverse Country Related Conditions	Unavailability of Infrastructure	4	Suspension
Contractor’s Lack of Experience	Contractor’s Lack of Experience in Country	4	Cost Overrun

Figure B.1: Case 1.1. Occurrence of landslides

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
1	50 months	2002	Turkey	150.000.000 €	Hydro Electrical Power Plant
Case Information					
Case ID	**Case Name**				
1.2	Missing contract statement				
Case Description					
During the construction process, client required contractor company to procure cement from another cement factory rather than the one determined in the contract clauses. Client claimed that the quality of the cements produced in the new factory is higher than pre-determined cement factory. However, transportation distance of new factory to the site is larger than the existing factory. In contract clauses transportation distance is specified as 222 km (that is distance between existing factory and site), on the other hand, distance of new factory is 478 km. In contract clauses, responsible party from compensation of costs raised due to scope changes were not defined, accordingly each party demanded from other the compensate additional transportation costs. The resolution of the conflict took considerable time and during this idle time, contractor company could not procure cement and consequently could not carry out construction works.					
Case Summary					
Vulnerability Factor	**Vulnerability Source**		**Rating**	**Consequence**	
Client’s Incompetency	Client’s Unclarity of Objectives		3	Interruption	
Contract Specific Problems	Vagueness of Contract Clauses		4	Conflict between parties	

Figure B. 2: Case 1.2. Missing contract statement

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
1	50 months	2002	Turkey	150.000.000 €	Hydro Electrical Power Plant
Case Information					
Case ID	**Case Name**				
1.3	Delay in site hand-over				
Case Description					
Contractor company could not start the construction process within the planned schedule, due to client’s disability to hand-over the construction site and site facilities. Client did not provide plants such as batching plant, crushing plant, required workshops, and construct diversion tunnels. Lack of plants and delays in the site hand-over were resulted in the time overrun (441 days delay) in the commencement date for "Set up Site" activity. Delay of the implementation of site facilities resulted contractor company in additional costs. These costs were, additional cost for erecting temporary site facilities, accommodation and transportation cost of site staff and workers, and standstill costs of each equipment. Contractor company claimed that, client is the responsible party from compensation of time and cost overruns that were occurred due to delays in the implementation of site facilities. Although client accepted to compensate loss of the contractor company , excessive amount of paper works that should be prepared and approved by the client company, took considerable time to respond to their needs. Hence, excessive amount of bureaucratic works lead to lags in the payments.					
Case Summary					
Vulnerability Factor	**Vulnerability Source**		**Rating**	**Consequence**	
Client’s Incompetency	Client’s Poor Managerial and Organizational		4	Delay	
Contractor’s Lack of Resources	Contractor’s Lack of Technical Resources		3	Cost overrun	
Adverse Site Condition	Lack of Site Facilities		4	Delay	

Figure B. 3: Case 1.3. Delay in site hand-over

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
1	50 months	2002	Turkey	150.000.000 €	Hydro Electrical Power Plant
Case Information					
Case ID	**Case Name**				
1.4	Electricity cuts				
Case Description					
During the construction process, frequent electricity cuts occurred which lead to stop the construction activities, especially which were performed with the electrical devices and equipment. Additionally, due to lack of a warning system making aware of possible electricity cuts, equipment and devices are damaged. Idle times during the electric cuts and damage of equipment and devices adversely affected performance of contractor company. Hence, in order to avoid equipment damages, and decrease the idle times, company used generators. In the contract clauses, generators were specified as secondary electricity sources, and responsible party from the additional costs that can rise due to the high unit price of diesel, was specified as contractor. As a result, company had to pay cost of diesel to carry out construction activities that were performed with the electrical devices and equipment					
Case Summary					
Vulnerability Factor		**Vulnerability Source**		**Rating**	**Consequence**
Adverse Site Condition		Lack of Site Facilities		3	Interruption
Contractors' Lack of Resources		Contractor's Lack of Technical Resources		3	Cost overrun

Figure B. 4: Case 1.4. Electricity cuts

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
1	50 months	2002	Turkey	150.000.000 €	Hydro Electrical Power Plant
Case Information					
Case ID	**Case Name**				
1.5	Wrong application of escalation formula				
Case Description					
In order to protect contractor from unforeseen price increases, an escalation (price difference) clause has been agreed between the contractor and the client in contracting process. Although, an escalation formula can only be used for the compensation of the price increases in the construction market, it was used in this project when the contractors' construction market had a negative escalation value. This is due to missing statements in the contract clauses about the conditions of the application of escalation formula as well as not recognizing the flaw of contract clauses and carrying out faulty calculations by the client company staff. Due to negative part of the escalation formula, actual prices are smaller than the contract price; therefore some deductions were taken from the contractor. As a result, due to missing statements in the contract and wrong application of the escalation formula by the clients' company staff, additional cost was cut from the contractor. Contractor demanded client to revise escalation calculations and re-pay the amount that had been cut from them, but client claimed that, it was contractors' responsibility to define escalation formula in the contract clauses. Client concluded that contractor is the responsible party from the missing statements about the formula and its application procedure, and his company would not re-pay the additional cost. Although, in the end conflicts between contractor and client were solved, the process took considerable time and client did not pay progress payments during this period					
Case Summary					
Vulnerability Factor		**Vulnerability Source**		**Rating**	**Consequence**
Contract Specific Problems		Contract Errors		3	Conflict between parties
Clients' Incompetency		Clients' Poor Staff Profile		3	Cost Overrun

Figure B. 5: Case 1.5. Wrong application of escalation formula

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
2	30 months	2009	Kazakhstan	50.000.000 $	Housing

Case Information	
Case ID	**Case Name**
2.1	Strict requirement for local partner

Case Description
Governmental regulations of the host country require having a local partner in order to get work permits for foreign laborers. To comply with this requirement and get work permits for our laborers, company signed a contract with a local partner and hired local workers. However, the complexity of construction method was high and the local partner has not been experienced in this kind of construction project. Although our workers were also participating in the project and working at the site, they are less in number when compared with the number of employed foreign labor, and their contribution was not sufficient to cope with the complexity of the construction method. Hence, lack of experience and qualifications of the local workers and partner resulted in quality problems. During the inspection of the site quality manager, several defects were detected which in turn lead to extensive rework. Quality problems, excessive rework and low productivity rates caused time delays and increased additional rework and overhead costs.

Case Summary			
Vulnerability Factor	**Vulnerability Source**	**Rating**	**Consequence**
Adverse Country Related Conditions	Restriction for Foreign Companies	3	Cost overrun
Contractor’s Lack of Resources	Contractor’s Lack of Technical Resources	4	Cost overrun

Figure B. 6: Case 2.1. Strict requirement for local partner

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
2	30 months	2009	Kazakhstan	50.000.000 $	Housing

Case Information	
Case ID	**Case Name**
2.2	Strict requirements to obtain work permits

Case Description
Host country possesses strict requirements for foreign companies about getting visa, residency and employments permits of foreign workers and staff. For instance, workers and staff can only take 2 months visa and after the 2 months duration, they should again request for a new visa. On the other hand, after requesting for a new visa, due to high level of bureaucracy of the host country, workers and staff had to wait a considerable time to obtain permits and to get visa. Therefore, as a repetitive cycle, after 2 months working periods, due to unavailability of labor that were waiting the visa and employment permits, the progress of the construction activities had to slow down. These interruptions of the work caused decreases in the productivity of the construction activities as well as increases in the labor cost due to cost of permits and visa.

Case Summary			
Vulnerability Factor	**Vulnerability Source**	**Rating**	**Consequence**
Adverse Country Related Conditions	Restriction for Foreign Companies	3	Cost overrun
Adverse Country Related Conditions	High Level of Bureaucracy	3	Interruption

Figure B. 7: Case 2.2 Strict requirements to obtain work permits

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
3	20 months	1982	Libya	10.000.000 $	Housing Project
Case Information					
Case ID	**Case Name**				
3.1	Strict requirements to export construction material				
Case Description					
During the contracting process, host country market conditions were completely available to provide construction material. On the other hand, after the contractor set the construction site and implemented site facilities, they faced with a problem that, the ruler of host country, had forbidden exporting several types of construction materials. Contractor requested special permits for the export of materials from the governmental departments of the host country and received them with a two month delay. At the end, due to instability of the laws and regulations of the host country, during the two months period contractor failed to provide construction material and construction process could not carried out with the expected level of productivity. Indeed, during this time some of the construction works were stopped, which cause additional accommodation and transportation cost of site staff and workers, and standstill costs of some equipment.					
Case Summary					
Vulnerability Factor		**Vulnerability Source**		**Rating**	**Consequence**
Adverse Country Related Conditions		Unavailability of Material		4	Interruption
Adverse Country Related Conditions		Immaturity of Legal System		4	Interruption

Figure B. 8: Case 3.1. Strict requirement to export construction material

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
3	20 months	1982	Libya	10.000.000 $	Housing Project
Case Information					
Case ID	**Case Name**				
3.2	Theft of construction equipment				
Case Description					
Contractor company faced cost overrun due to theft of bowser from the construction site. A day after of theft, their staff found bowser at 20-30 km far away from construction site and immediately they tested bowser to understand whether it was damaged. After some serial tests, it was concluded that bowser cannot be used again and while they reported their damage to the related governmental departments, they responded that if contractor company provide some required documents, they would allocate contractor company's damage. Although all required documents such as bowser license, equipment registration, clearance, import certificate, plate documents were provided to the governmental departments, due to bureaucratic problems and some immaturity clauses of their legal documents, for a considerable time they did not do anything to allocate contractor company's damage. At the end, although they provided a new bowser, during this idle time contractor company had to continue site works without one of bowser which their decreased productivity.					
Case Summary					
Vulnerability Factor		**Vulnerability Source**		**Rating**	**Consequence**
Adverse Country Related Conditions		High Level of Bureaucracy		2	Interruption
Contractor’s Lack of Resources		Contractor’s Lack of Technical Resources		2	Interruption

Figure B. 9: Case 3.2. Theft of construction equipment

<table>
<tr><th colspan="6">Project Information</th></tr>
<tr><th>Project ID</th><th>Duration</th><th>Year</th><th>Country</th><th>Budget</th><th>Type</th></tr>
<tr><td>4</td><td>45 months</td><td>2003</td><td>Latvia</td><td>35.000.000 €</td><td>Housing, business center</td></tr>
<tr><th colspan="6">Case Information</th></tr>
<tr><th>Case ID</th><th colspan="5">Case Name</th></tr>
<tr><td>4.1</td><td colspan="5">Strict fire precaution requirements</td></tr>
<tr><th colspan="6">Case Description</th></tr>
<tr><td colspan="6">The client of the project is the government of Latvia. Latvian government possess strict requirements to enable fire precaution. Due to clients' incompetency of early and continuous involvement and incompetency of interpreting own expectations, these requirements were not stated to contractor company prior to the design stage of the project. Thus, contractor company carried out design process based on Turkish design standards and specifications. However, during the construction stage, inspectors of the client reported that materials which were used in the exterior walls, were not in accordance with the fire regulations. For a 30- story building, designers decided to cover the exterior walls with a compact laminate which belongs to the A2 class material. On other the hand, inspector of the client stated that, for the buildings taller than the 14-storey building, A1 class exterior wall material should be used. Therefore, contractor company had to stop the covering of the exterior walls, remove the existing A2 class covering, and cover with a A1 class covering material, all of which resulted in considerable amount of additional cost.</td></tr>
<tr><th colspan="6">Case Summary</th></tr>
<tr><th colspan="2">Vulnerability Factor</th><th colspan="2">Vulnerability Source</th><th>Rating</th><th>Consequence</th></tr>
<tr><td colspan="2">Strict Requirements</td><td colspan="2">Strict Health and Safety Requirements</td><td>3</td><td>Cost Overrun</td></tr>
<tr><td colspan="2">Clients’ Incompetency</td><td colspan="2">Client's Poor Managerial and Organizational Ability</td><td>3</td><td>Interruption</td></tr>
</table>

Figure B. 10: Case 4.1. Strict fire precaution requirements

<table>
<tr><th colspan="6">Project Information</th></tr>
<tr><th>Project ID</th><th>Duration</th><th>Year</th><th>Country</th><th>Budget</th><th>Type</th></tr>
<tr><td>4</td><td>45 months</td><td>2003</td><td>Latvia</td><td>35.000.000 €</td><td>Housing, business center</td></tr>
<tr><th colspan="6">Case Information</th></tr>
<tr><th>Case ID</th><th colspan="5">Case Name</th></tr>
<tr><td>4.2</td><td colspan="5">Poor staff profile of client company</td></tr>
<tr><th colspan="6">Case Description</th></tr>
<tr><td colspan="6">Although work permits for foreign workers are not restricted or forbidden in Latvia rules and regulations, client of the project required to employ Latvian workers of the client company rather than the Turkish workers. On the other hand, the project was a high-rise housing project and Latvia workers have not enough experience regarding this type of project. At the beginning contractor company employed Latvian workers but they faced some problems such as some construction tasks were carried out slow in progress and low in quality due to their technical incompetency. Therefore, they had to obtain special work permits for experienced Turkish workers and during this process a lot of paperwork and idle waiting times lead contractor company an additional overhead cost. In addition, contractor company could not get any progress payments due to not carrying out construction works during the one month idle time period.</td></tr>
<tr><th colspan="6">Case Summary</th></tr>
<tr><th colspan="2">Vulnerability Factor</th><th colspan="2">Vulnerability Source</th><th>Rating</th><th>Consequence</th></tr>
<tr><td colspan="2">Client’s Incompetency</td><td colspan="2">Client Level of Bureaucracy</td><td>4</td><td>Suspension</td></tr>
<tr><td colspan="2">Client’s Incompetency</td><td colspan="2">Client's Poor Staff Profile</td><td>3</td><td>Interruption</td></tr>
</table>

Figure B. 11: Case 4.2. Poor staff profile of client company

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
4	45 months	2003	Latvia	35.000.000 €	Housing, business center
Case Information					
Case ID	**Case Name**				
4.3	Conflicts among subcontractor and project manager				
Case Description					
Contractor company signed with a subcontractor and a project manager companies. After signing a contract with both companies and starting to the construction works, contractor company realized that, there were some controversies between staff of two companies due to their nationality racism. During the project, coordination and communication among two parties were considerable poor, due to miscommunication there were so many rising conflicts about technical issues, indeed they blamed each other for faulty or missing works. Contractor company could not solve coordination and communication management problems among these parties and of course it was contractor company's fault that they did not perform a detailed search about these companies before signing contracts. At the end, they could not solve list of problems and it resulted in suspension of construction works.					
Case Summary					
Vulnerability Factor		**Vulnerability Source**		**Rating**	**Consequence**
Contractors' Lack of Managerial Skills		Poor Human Resource Management		4	Suspension
Contractors' Lack of Managerial Skills		Poor Communication Management		4	Suspension

Figure B. 12: Case 4.3. Conflicts among subcontractor and project manager

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
4	45 months	2003	Latvia	35.000.000 €	Housing, business center
Case Information					
Case ID	**Case Name**				
4.4	Occurrence of economic crisis				
Case Description					
In the earlier period of the project, contractor company did not have enough financial resources to operate the project. Thus, they had to finance project by taking loans from bank and selling some houses for individuals who were also taking loan from banks to buy the houses. On the other hand, due to instability of the economic conditions of the country, after a while start of the project, economic crisis was occurred, which caused banks to have strict requirements while providing loans. Therefore, individuals could not take loans to buy houses and contractor company faced difficulty to finance the project. Thus, they had to stop construction works till they would find a new financial source.					
Case Summary					
Vulnerability Factor		**Vulnerability Source**		**Rating**	**Consequence**
Adverse Country Related Conditions		Instability of Economic Conditions		4	Suspension
Contractor's Lack of Resources		Contractor's Lack of Financial Resources		5	Suspension

Figure B. 13: Case 4.4. Occurrence of economic crisis

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
4	45 months	2003	Latvia	35.000.000 €	Housing, business center
Case Information					
Case ID	**Case Name**				
4.5	Unavailability of local material				
Case Description					
Host country is known as facing harsh winter conditions due to its geographic location, therefore every contractor firm seeks for opportunity to do business in spring and summer time in that country. On the other hand, this brings the problem of excessive amount of construction works undertaken at summer time. Due to excessive on-going construction facilities during this period, some construction materials, especially cement, cannot be supplied in sufficient amounts due to existence of only one cement factory in host country and inadequacy of cement production. Therefore, construction firms had only two options to provide material to site; using ready-mixed concrete or providing cement from another country. First option cannot also be a solution due to requirement of high amount of ready-mixed concrete, so contractor company decided on second option, to import cement from another country. On the other hand, importing cement from another country added high transportation costs to material cost which could not be forecasted during the cost estimation process.					
Case Summary					
Vulnerability Factor		**Vulnerability Source**		**Rating**	**Consequence**
Adverse Country Related Conditions		Unavailability of Local Material		4	Cost Overrun

Figure B. 14: Case 4.5. Unavailability of local material

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
4	45 months	2003	Latvia	35.000.000 €	Housing, business center
Case Information					
Case ID	**Case Name**				
4.6	Theft in site storage area				
Case Description					
Contractor company's staff observed that, at midnight some people came to the site storage area, site guard, who was also from host country, opens the barriers and they took some materials like glass, steel wire mesh and steel sheets. While their staff asked to site guard this incident, he was stated that, this incident was not a theft, they were only taking their own needs from people who do not need them. Therefore, different perceptions, beliefs and ethics was lead to difficult situation for both parties. Nevertheless, firm staff needed to supply those construction materials for second time which caused additional cost to the project.					
Case Summary					
Vulnerability Factor		**Vulnerability Source**		**Rating**	**Consequence**
Contractor's Lack of Experience		Contractor's Lack of Experience in Country		2	Cost Overrun

Figure B. 15: Case 4.6. Theft in site storage area

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
5	36 months	1997	Turkey	80.000.000 ₺	Housing
Case Information					
Case ID	**Case Name**				
5.1.	Poor site investigation				
Case Description					
Design process of the housing project was started without having sufficient information about the geological conditions due to incompetency of contractor company's technical staff in soil investigation tests. During the construction, contractor company encountered with the instable geological conditions such as site heterogeneities and poor bearing capacity of soil. Thus, they had to stop the construction facilities, perform site investigation process once again and investigate potential defects in construction facilities. At the end, it was required from contractor company to construct blockages and injections to provide stable conditions and rework the potential defects, which resulted in the additional cost.					
Case Summary					
Vulnerability Factor	**Vulnerability Source**		**Rating**	**Consequence**	
Contractor’s Lack of Resources	Contractor's Lack of Staff		4	Cost overrun	
Uncertainty of Geological Conditions	Uncertainty of Geological Conditions		3	Suspension	

Figure B. 16: Case 5.1. Poor site investigation

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
5	36 months	1997	Turkey	80.000.000 ₺	Housing
Case Information					
Case ID	**Case Name**				
5.2.	Conflicts among design specifications				
Case Description					
The housing project was interrupted due to conflicts among earthquake regulations and excessive amount of bureaucratic correspondences with ministry of public works. Correspondences were raised due to conflict of a statement between two earthquake standards, TS708 and ABYYHY. According to TS708, ratio of tensile strength to the yield strength of steel should be minimum 1.10, whereas, it was stated in ABYYHY as 1.25. Although contractor company obey ABYYHY specifications, construction auditing companies performs controls based on TS708. Therefore, to avoid possible errors and conflicts during the controlling process of construction, design team stopped carrying out design calculations and drawings and their management staff interpreted contradictions among specification through correspondences that were carried out with the ministry of public work. Nevertheless, due to excessive bureaucracy involved in governmental departments, ministry did not provide any solution, indeed waiting information and feedback from them lead to suspension of design process. Due to this idle time, duration of design process exceeded the planned duration which increased planned overhead costs of design stage.					
Case Summary					
Vulnerability Factor	**Vulnerability Source**		**Rating**	**Consequence**	
Project Complexity	Complexity of Design		3	Suspension	
Adverse Country Related Conditions	High level of Bureaucracy		4	Delay	

Figure B. 17: Case 5.2. Conflicts among design specifications

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
6	24 months	2010	Turkey	70.000.000 €	Shopping mall
Case Information					
Case ID	**Case Name**				
6.1.	Poor performance of subcontractor				
Case Description					
Contractor company hired a subcontractor company to carry out geological investigation in the shopping mall project and the design process was performed based on the geotechnical data received from the subcontractor. In construction process, they faced some problems about foundation such as there were unexpected cracks on the concrete walls of foundation as well as ground was collapsed. Thus, they had to stop construction works and carry out a detailed geotechnical investigation with another subcontractor. After detailed investigation of these cracks, it was understood that, the first subcontractor did not collected geological information, not examined ground conditions and not carried out site investigation, surveys and tests properly, indeed there were some errors in site survey data. The technical incompetency of subcontractor was resulted in design errors, renewal and rework of the mat foundation.					
Case Summary					
Vulnerability Factor	**Vulnerability Source**		**Rating**	**Consequence**	
Contractors' Lack of Resources	Contractors' Lack of Technical Resources		4	Cost overrun	

Figure B. 18: Case 6.1. Poor performance of subcontractor

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
6	24 months	2010	Turkey	70.000.000 €	Shopping mall
Case Information					
Case ID	**Case Name**				
6.2	Complexity of design				
Case Description					
Contractor company's design and structural engineering team could not carry out design process properly and in time due to high complexity involved in the project. Their team had to revise architectural and structural design several times in order to avoid possible missing or erroneous items. This resulted in the late design decisions, and delays in the delivery of the structural drawings to the site engineer. Engineer team concluded to stop site works, take consultant from another design company and carry out design revisions with the consultant company. At the end, delays in the site works and hiring cost of the consultant company resulted in considerable additional cost to the contractor company.					
Case Summary					
Vulnerability Factor	**Vulnerability Source**		**Rating**	**Consequence**	
Project Complexity	Complexity of Design		3	Suspension	
Contractors' Lack of Resources	Contractors' Lack of Technical Resources		4	Cost Overrun	

Figure B. 19: Case 6.2. Complexity of design

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
6	24 months	2010	Turkey	70.000.000 €	Shopping mall
Case Information					
Case ID	**Case Name**				
6.3	Poor communication among teams				
Case Description					
In shopping mall project, due to poor communication among structural and design team, delivery of the structural and architectural drawings to the site was delayed which caused some construction site activities stay on hold for a long period. On the other hand, contractor company had to pay equipment, labor and overhead cost even if the construction activities was stopped. Thus, poor communication among teams lead to suspension of construction works and additional stand-still costs.					
Case Summary					
Vulnerability Factor		**Vulnerability Source**		**Rating**	**Consequence**
Engineer's Incompetency		Managerial Incompetency of Engineer		3	Suspension
Contractor's Lack of Managerial Skills		Poor Communications Management		3	Suspension

Figure B. 20: Case 6.3. Poor communication among teams

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
6	24 months	2010	Turkey	70.000.000 €	Shopping mall
Case Information					
Case ID	**Case Name**				
6.4	Incompetent planning team				
Case Description					
Contractor company prepared a work schedule as a part of the execution scenario and take the approval of project manager who would follow and update the construction works. On the other hand, project manager requested contractor company to prepare a more realistic resource loaded schedule under CPM in order to provide favorable means to keep the construction activities under control. On the other hand, they faced some difficulties to provide such program, and their planning team were inexperienced in preparing work schedule with resource loadings on Primavera or MS Project. At the end, final work schedule could be prepared with six months delay.					
Case Summary					
Vulnerability Factor		**Vulnerability Source**		**Rating**	**Consequence**
Engineer's Incompetency		Technical Incompetency of Engineer		3	Delay
Contractor's Lack of Resources		Contractors' Lack of Technical Resources		3	Suspension

Figure B. 21: Case 6.4. Incompetent planning team

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
7	24 months	1975	Turkey	25.000.000 ₺	Housing
Case Information					
Case ID	**Case Name**				
7.1.	Rehabilitation of foundation				
Case Description					
Soil type of the location was gray sandstone which was known as releasing its strength while mixed with water. After project completion, foundation consolidations were occurred and resulted in cracks on foundation and upper structure walls. While these cracks were tested by engineers and it was found that they occurred due to poor geotechnical investigation, wrong soil test methods and improper design. In addition, following this time, municipality excavated the main road as a part of an ongoing infrastructure works and due to a negligence, sewer lines were damaged which caused leakage of water to the foundation. Leakage of water to the gray sandstone soil leads to decrease in the soil strength. Although, contractor company attempted to rehabilitate, renew and rework the foundation, they have been never experienced such an unexpected situation. Therefore, they had to take consultancy from international experts. All of this renewal process required getting approvals from municipality and government which took considerable amount of the bureaucratic works. As a result, they faced excessively large amount of cost overrun due to taking consultancy from international experts, preparing required documents, conducting required tests, supply of special equipment, measurement instruments, and payments for the skilled expertise staff who conducts and monitors special tests.					
Case Summary					
Vulnerability Factor	**Vulnerability Source**		**Rating**	**Consequence**	
Uncertainty of Geological Conditions	Uncertainty of Geotechnical Investigation		3	Cost Overrun	
Engineer's Incompetency	Technical Incompetency of Engineer		4	Cost Overrun	

Figure B. 22: Case 7.1. Rehabilitation of foundation

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
8	26 Months	2004	Poland	30.000.000 €	Fast Train
Case Information					
Case ID	**Case Name**				
8.1.	Problems in obtaining tree-cutting permits				
Case Description					
In fast tram project, open-trench technique was used as the method of construction. This method requires, flattening of wooden area, cutting trees, prior to the excavation works. So, contractor company had to obtain tree-cutting permits from the governmental departments. Due to strict environmental requirements of the host country, company's tree-cutting permission was approved after several bureaucratic works and special permissions from other several departments. In the beginning, company planned to start construction works on June, but due to this idle time, it was delayed to November. In addition, since company had to start construction on November, workers were exposed to work on harsh winter conditions which decreased their productivity. In order to compensate the time delay, company had to accelerate some construction works, which in turn resulted in some erroneous and low quality products. Hence, reworks of these produced resulted in additional costs.					
Case Summary					
Vulnerability Factor	**Vulnerability Source**		**Rating**	**Consequence**	
Strict Requirements	Strict Environmental Requirements		4	Delay	
Contractor's Lack of Managerial Skills	Poor Project Quality Management		4	Cost Overrun	

Figure B. 23: Case 8.1. Problems in obtaining tree-cutting permits

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
8	26 Months	2004	Poland	30.000.000 €	Fast Train
Case Information					
Case ID	**Case Name**				
8.2.	Changes in type of the construction material				
Case Description					
Although in the approved design, bituminous paint was defined as the material type, an expert of the client company ordered the application of Sika Inertol Poxitar F material to the tunnel walls. Expert stated that, Sika Inertol Poxitar F should be applied after surface preparation, and it requires two layers application and above a minimum temperature 5 degrees C. While compared with the bituminous paint, application of Sika is more time-consuming. Thus, application of Sika caused delays in the planned duration of painting activity.					
Case Summary					
Vulnerability Factor		**Vulnerability Source**		**Rating**	**Consequence**
Client's Incompetency		Client's Unclarity of Objectives		2	Delay

Figure B. 24: Case 8.2. Changes in type of the construction material

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
8	26 Months	2004	Poland	30.000.000 €	Fast Train
Case Information					
Case ID	**Case Name**				
8.3.	Uncertainty of soil type				
Case Description					
Contractor company determined soil type of project location as non-cohesive sand soils in the geotechnical investigation. On the other hand, during the excavation works, they encountered with organic plastic soil type which could not foreseen in geotechnical investigation. Thus, they had to replace the soil, backfill with proper soil and compact it. Hence, taking out all the organic plastic soil layer, replacing soil and backfilling by layers, resulted in additional costs to the contractor company.					
Case Summary					
Vulnerability Factor		**Vulnerability Source**		**Rating**	**Consequence**
Uncertainty of Geological Problems		Uncertainty of Geological Investigation		3	Cost Overrun

Figure B. 25: Case 8.3. Uncertainty of soil type

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
9	33 months	2009	Azerbaijani	75.000.000 $	Housing
Case Information					
Case ID	**Case Name**				
9.1.	Defects in frame components				
Case Description					
While site engineer of client was supervising the construction facilities, he observed that, there were several defects and errors in the frame components of buildings. He required from contractor to demolish and rework the frame components which caused additional rework cost to contractor company. In contract clauses, responsible party from additional costs was not defined which lead to disputes between contractor company and client. Although, contractor was condemned in additional cost of rework after a long period of negotiations, during this idle time contractor could gain from progress payments from client.					
Case Summary					
Vulnerability Factor		**Vulnerability Source**		**Rating**	**Consequence**
Engineer's Incompetency		Technical Incompetency of Engineer		4	Interruption
Contract Specific Problems		Vagueness of Contract Clauses		3	Conflicts between parties

Figure B. 26: Case 9.1. Defects in frame components

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
9	33 months	2009	Azerbaijani	75.000.000 $	Housing
Case Information					
Case ID	**Case Name**				
9.2.	Tight project schedule				
Case Description					
Client required contractor company to finish the project in six months, which was a very tight project schedule for such a project. Contractor company claimed that, in order to accelerate the project and finish it within six months, high amount of construction materials and equipment were required. Although contractor company attempted to provide materials and equipment, such amount of resources were unavailable in host country. In addition, there were other obstacles that hinder contractor company to finish the project in schedule. For instance, after construction of walls, it needs to wait few days to coat and after coating of walls, additional days are required to paint them. Thus, due to shortage of materials and equipment as well as some other constraints, contractor company could not finished the project in schedule.					
Case Summary					
Vulnerability Factor		**Vulnerability Source**		**Rating**	**Consequence**
Strict Requirements		Strict Project Management Requirements		3	Delay
Adverse Country Related Conditions		Unavailability of Material		3	Delay

Figure B. 27: Case 9.2. Tight project schedule

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
10	20 months	2010	Turkey	45.000.000 €	Shopping mall

Case Information	
Case ID	**Case Name**
10.1	Unclarity of standards and specifications

Case Description

Client company, contractor company and subcontractors of the project were Turkish and project financer of client was German. In contract clauses, neither Turkish parties nor German party specified what type of specifications were required to be used for the design and construction processes. In construction, contractor company used Turkish standards and specifications in architectural and structural design, as well as subcontractors performed construction tasks based on this design. However, in a visit of auditor of project financer to the site, he claimed that, he had required to use German specifications and standards from contractor, and Turkish specifications and standards could not achieve his expectations and provide his requirements. He added that, his expectations were far from what was constructed. It was stated by contractor firm expert that, auditor of project financer required contractor to use German specification after the construction process had started. Thus, contractor company had to stop construction works and carry out high amount of reworks.

Case Summary			
Vulnerability Factor	**Vulnerability Source**	**Rating**	**Consequence**
Contract Specific Problems	Vagueness of Contract Clauses	4	Conflict between parties
Strict Requirements	Strict Project Management Requirements	3	Interruption

Figure B. 28: Case 10.1. Unclarity of standards and specifications

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
11	20 months	2000	Turkey	18.000.000 €	Housing

Case Information	
Case ID	**Case Name**
11.1	Conflicts among municipality and contractor company

Case Description

The client of the housing project was the government of Turkey. During the construction, landslides were occurred on the access road to the construction site. Although, in contract clauses, goverment or related municipality was determined as responsible party from unexpected events, they did not provide any necessary corrective action to the damage of landslides. Contractor company claimed that they need workforce and equipments to renew soil from the road. However, goverment and municipality did not supply any of them. They claimed, there were some missing contract clauses in contract and they were not the responsible party from the compensation of additional cost, thus they would not finance the expenses of labour and equipments. After several correspondences and meetings, municipality agreed to supply workforce and equipment, but this process took a considerable time. As a result, occurrence of landslides and following shortage of

Case Summary			
Vulnerability Factor	**Vulnerability Source**	**Rating**	**Consequence**
Unexpected Events	Natural Catastrophes	4	Interruption
Contractor's Lack of Resources	Contractor's Lack of Technical Resources	3	Suspension
Contract Specific Problems	Vagueness of Contract Clauses	4	Conflicts between parties

Figure B. 29: Case 11.1 Conflicts among municipality and contractor company

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
12	24 months	1992	Russia	45.000.000 $	Housing
Case Information					
Case ID	**Case Name**				
12.1	Shortage of fresh water				
Case Description					
Before setting up construction site, client and municipality provided fresh water source to the construction site. On the other hand, in construction process, it was observed that iron was mixed to the well of the source, so fresh water was polluted. Due to unavailability of fresh water supply of host country, contractor company's staff and labor faced difficult times.					
Case Summary					
Vulnerability Factor		**Vulnerability Source**		**Rating**	**Consequence**
Adverse Country Related Conditions		Unavailability of Infrastructure		2	Interruption

Figure B. 30: Case 12.1 Shortage of fresh water

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
13	12 months	1997	Turkey	55.000.000 $	Light Rail System
Case Information					
Case ID	**Case Name**				
13.1	Changes in design				
Case Description					
Design changes in the light rail system project resulted in approximately %40 cost overrun. Those changes include, change of station size, enlargement of right of way and length of the tunnels. In bidding phase, those changes could not be foreseen, and method of construction was selected based on the initial design of the project. However, after those changes in order to be complied with the present conditions, contractor company had to change method of construction that was determined in contract clauses. For instance, company decided to change retaining systems and give up using bored tunnels.					
Case Summary					
Vulnerability Factor		**Vulnerability Source**		**Rating**	**Consequence**
Project Complexity		Complexity of Design		3	Cost Overrun

Figure B. 31: Case 13.1 Changes in design

Project Information					
Project ID	**Duration**	**Year**	**Country**	**Budget**	**Type**
13	12 months	1997	Turkey	55.000.000 $	Light Rail System

Case Information	
Case ID	**Case Name**
13.2	Inflation in material prices

Case Description
Contractor company could not start the construction process within the planned schedule, due to client's disability to hand-over the construction site and site facilities. Contractor claimed nearly 750 days of time extension, to finish the project within the expected quality. Although client company accepted time extension, he claimed that he would not be responsible from additional prices rised due to high level of inflation existent in the host country. Due to inflation of the material prices, actual prices of the material were extremely higher than those specified in contract. For instance, cement price had an increase of %40, diesel, steel, rebar and labor costs had %95, %45, %25, %20, respectively. As a result, average cost overrun of the material and labor costs was about %45.

Case Summary			
Vulnerability Factor	**Vulnerability Source**	**Rating**	**Consequence**
Adverse Country Related Conditions	Instability of Economic Growth	3	Cost Overrun
Client's Incompetency	Poor Managerial and Organizational Ability	3	Delay

Figure B. 32: Case 13.2 Inflation in material prices

APPENDIX C

This chapter presents the documents that were prepared prior to usability testing sessions. The documents consist, test scenarios and tasks, post-test questionnaires, and post-test questionnaires. To be noted that, post-task questionnaires are given in Chapter 6 when presenting the findings of these questionaires.

C.1. Test Scenarios and Tasks

Scenario 1: Ease of creating a project

You are carrying out an international construction project. During the project, some problems are occurred and you think that these may be resulted in cost overrun. Thus, you want to quantify probable cost overrun percentage of your project by conducting risk assessment using the risk-mapping tool.

Task 1: You need to create a new project and assign your project information. The project information is given as follows;

Project name:	Housing project
Country Name:	Russian Federation
Project Type:	Residential Building
Project Description:	Housing complex
Start Date:	08.10.2011
Duration:	24
Contract Value:	40.000.000 USD
Contract Type:	design-build (DB)
Payment Type:	unit price (UP)
Company's Role in the Project	contractor
Owner:	government

Scenario 2: Ease of assigning attribute default weights

You decided to use attributes to assess the rating of Complexity of Design, which is the vulnerability source of Project Complexity. You want to use default weights when assessing the attributes of Complexity of Design.

Task 1: You decided to assign attribute weights as 0.2, 0.3, 0.15, 0.25, 0.35. If necessary, normalize weights.

Scenario 3: Ease of using attributes

When carrying out risk assessment, you need to assign ratings of vulnerability sources that are represented on risk map. You decided to start risk assessment process by assigning the rating of Project Complexity. You want to use attributes to assess the rating of it.

Task 1: For complexity of design, you decided to use default weights and you assigned the attribute ratings as; 2, 3, 3, 2, 4 respectively.
Task 2: For low constructability, you decided to use equal weights and you assigned the attribute ratings as; 1, 2, 2, 3, 4, 1, 5 respectively.
Task 3: For complexity of construction method, you assigned attribute weights as 0.45, 0.75 and ratings as 3, 4 If necessary, you can normalize the weights.

Scenario 4: Ease of using lessons learned database

After you completed the Project Complexity, you decided to assign rating of Uncertainty of Geological Conditions. You examined that, there exists a similar previous project that involves a project case occurred due to Uncertainty of Geological Investigation. Thus, you decided to use lessons learned database and assign the same rating with the retrieved project case.

Task 1: You examined that, several project cases are occurred due to Uncertainty of Geological Investigation. Thus, you need to refine results to select only the cases whose project type is the same as your project.
Task 2: You decided that the word “investigation” is critical to evaluate the case description. Thus, you searched the word ‘investigation’ within the case descriptions.

Task 3: You decided that, your project is exposed to same conditions and problems. Thus, you decided to assign rating of Uncertainty of Geological Investigation as was assigned in the retrieved case.

Scenario 5: Ease of using risk map

You need to assign ratings of all other vulnerability sources in order to quantify the cost overrun percentage of your project. You assigned the ratings of Project Complexity and Uncertainty of Geological Investigation previously. Now, you need to define the rating of other vulnerability sources. You decided to rate them without using attributes and lessons learned database.

Task 1: You decided to assign ratings for other vulnerability source. Their ratings are given as follows;

Vulnerability	**VS ID**	**Vulnerability Source**	**Rating**
Adverse Country Related Conditions	VS1	Instability of Economic Condition	3
	VS2	Instability of Government	2
	VS3	Instability of International Relations	3
	VS4	Social Unrest	2
	VS5	High Level of Bureaucracy	4
	VS6	Immaturity of Legal System	2
	VS7	Restrictions for Foreign Companies	1
	VS8	Unavailability of Local Material	3
	VS9	Unavailability of Equipment	4
	VS10	Unavailability of Local Labor	5
	VS11	Unavailability of Local Subcontractor	1
	VS12	Unavailability of Infrastructure	1
Strict Requirements	VS19	Strict Quality Requirements	2
	VS20	Strict Environmental Requirements	3
	VS21	Strict Health & Safety Requirements	4
	VS22	Strict Project Management Requirements	1
Contract Specific Problems	V23	Vagueness of Contract Clauses	3
	V24	Contract Errors	5
Engineer's Incompetency	V25	Technical Incompetency of Engineer	2
	V26	Managerial Incompetency of Engineer	1
	V27	Engineer's Lack of Financial Resources	3
Client's Incompetency	V28	Client's Unclarity of Objectives	2
	V29	Client's High Level of Bureaucracy	1
	V30	Client's Negative Attitude	4

	V31	Client's Poor Staff Profile	1
	V32	Client's Lack of Financial Resources	4
	V33	Client's Technical Incompetency	2
	V34	Client's Poor Managerial/ Organizational Abilities	1
Adverse Site Conditions	V35	Poor Site Supervision	2
	V36	Lack of Site Facilities	4
Contractor's Lack of Experience	V37	Contractor's Lack of Experience in Similar Projects	2
	V38	Contractor's Lack of Experience in Country	5
	V39	Contractor's Lack of Experience in Project delivery System	4
	V40	Contractor's Lack of Experience with Client	1
Contractor's Lack of Resources	V41	Contractor's Lack of Financial Resources	2
	V42	Contractor's Lack of Technical Resources	3
	V43	Contractor's Lack of Staff	2
Contractor's Lack of Managerial Skills	V44	Poor Project Scope Management	4
	V45	Poor Project Time Management	1
	V46	Poor Project Cost Management	2
	V47	Poor Project Quality Management	3
	V48	Poor Human Resource Management	5
	V49	Poor Communication Management	2
	V50	Poor Risk Management	1
	V51	Poor Procurement Management	1
Unexpected Events	V73	War/ Hostilities	1
	V74	Rebellion/ Terrorism	1
	V75	Natural Catastrophes	1

Task 2: You need to run the risk assessment to obtain the risk rating results.

Scenario 6: Ease of evaluating and reporting results

You completed the risk assessment process. Now, you decided to evaluate the risk assessment results.

Task 1: You wanted to learn the risk rating of Contractor's Lack of Managerial Skills. You recorded the rating as ____.

Task 2: You wanted to learn the impacts of paths having the ID of 5. You recorded the risk path impact as ___.

Task 3: You wanted to learn the probable cost overrun percentage of your project. Your recorded the cost overrun percentage as ___.

Task 4: You wanted to report and share risk rating results with your project manager. Thus, you need to assign report information. The report information is given as follows;

Project Name:	Housing Project
Report name:	Cost overrun
Report Ref. No.	1
Company name:	METU Construction
Company Address:	Dumlupınar Blv. 06500
Company phone:	2107575
Company mail	xyz@gmail.com

Scenario 7: Ease of using sensitivity analysis

You observed that your cost overrun percentage is extremely high. Thus, you want to implement some mitigation strategies in order to minimize the additional cost. Now, you are wondering that if the rating of vulnerability is decreased what will be the cost overrun percentage. Thus, you decided to carry out sensitivity analysis testing.

Task 1: You wanted to carry out sensitivity analysis for only Adverse Country Related Conditions. You wanted to obtain results as a bar chart.

Task 2: You wanted to carry out sensitivity analysis for both Adverse Country Related Conditions and Strict Requirements. You wanted to obtain results as a line chart.

Scenario 8: Ease of assigning a new case

You completed your on-going project. However, you wanted to store your knowledge that you gained throughout the project. Thus, you decided to store your knowledge into the lessons learned database.

Task 1: You need to store your knowledge in the form of project case. Thus, you need to add case into the tool.

Task 2: You need to describe your case as well as store it based on its case summary. The case description and case summary are given as follows;

Scenario 9: Ease of using the case library

After storing your knowledge, you wanted to examine your previous project cases from the case library.

Task 1: You wanted to search for the cases of the power plant project. You need to open cases of power plant project.

Task 2: After you opened its cases, you realized that you forgot its detailed project information. Thus, you decided to open the project information of power plant project.

C.2. Pre-Test Questionnaire

1. Name: ____

2. Date of graduation from undergrad: _____________

3. Grade Level: Graduate M.Sc. PhD

4. Age Group: 5-10 11-13 14-17 18-24 25-34 35-44 45-55 over 55

5. Gender: Female Male

6. Years Using the Computer: _______________

7. How frequently do you use software tools?

   Daily Weekly Monthly Occasionally Never

8. What is your purpose on using software tools? *(e.g., email, searching, read news, games, entertainment etc.)*

   ____

9. Do you use software tools as a part of your job/academic research? Yes No

10. What are your top five criteria in choosing software?

    ____

    ____

11. How would you rate your competency on using software tools? (On a scale 1 to 5, with 1 representing beginner and 5 advanced)

    1 2 3 4 5

C.3. Post-Test Questionnaire

1. What do you like most about the tool?

   ____

2. What do you like least about the tool?

   ____

3. Is there any task that is difficult for you to do?

   ____

4. What else should be included on the tool?

   ____

5. Are you satisfied with your experience using the tool?

   Extremely satisfied Very satisfied Moderately satisfied Slightly Satisfied Not at all

6. Would you like to make any comments or suggestions about the tool?

   ____

7. If the tool were available in market, how likely would you use tool it?

   Extremely likely Very likely Moderately likely Slightly Likely Not at all

8. If you are not likely to use the tool, why?

   I do not need a tool like this

   I do not want a tool like this

   I am satisfied with other risk management tools currently available

   Others _______________