A MULTI AGENT RISK ANALYSIS AND SHARING PLATFORM FOR INTERNATIONAL CONSTRUCTION PROJECTS

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ABSTRACT

A MULTI AGENT RISK ANALYSIS AND SHARING PLATFORM FOR INTERNATIONAL CONSTRUCTION PROJECTS

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The risks and complexities that are naturally inherent with construction projects and the diverging interests of the parties involved, cause deviations from the project objectives and make claims an unavoidable consequence in construction projects. Risk management is accepted as one of the critical success factors to handle the claim management process effectively. In construction management literature, while there are several studies to develop a mechanism for risk management, decision making and dispute resolution, none of them are qualified enough to cover all parts of the risk analysis and negotiation processes and to provide a realistic risk-budget sharing model. Limitations of the available analysis tools may be listed as the inability in properly describing the cause-effect relation between vulnerability and risks, inability in formulizing the interrelations of risks and relations between risks and cost overrun, inability in incorporating the risk sharing principles between project participants, contract clauses and risk management strategies directly into the computation of responsibility sharing of risks among parties. The aim of this thesis is to develop a new simulation platform that eliminates these shortcomings. With this platform, it will be possible to determine the probable risks and cost overrun by using a risk event memory consisting data regarding several completed projects, to design and simulate negotiation between project participants by considering contract conditions, short and long term objectives of the parties in order to determine the cost overrun values to be undertaken by project parties. The platform outcomes are compared with literature, tested by real projects and it has been proven to be usable and reliable.

Keywords: construction engineering and management, risk management, negotiation, claim management, multi agent systems

ÖZ

ULUSLARARASI İNŞAAT PROJELERİ İÇİN ÇOK ARACILI RİSK ANALİZ VE PAYLAŞIM MODELİ

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Uluslararası inşaat projelerinin doğasında var olan riskler ve karmaşıklıkların yanı sıra projeye dahil olan tarafların farklılaşan beklentileri proje hedeflerinden sapmalara neden olmakta ve taraflar arasında yaşanan talep görüşmelerini inşaat projelerinin kaçınılmaz bir gerçeği haline getirmektedir. Bu sürecin en etkin şekilde yürütülebilmesi için risk yönetimi kritik başarı faktörlerinden biri olarak kabul edilmektedir. Her ne kadar, yapım yönetimi literatüründe risk yönetimi, karar verme süreçleri ve anlaşmazlıkların çözümlenmesi için destek sistemleri geliştirmeye yönelik çalışmalar olsa da, bu çalışmaların hiç biri gerçekleşen pazarlık sürecini bütün yönleriyle ele almamakta ve gerçekçi bir risk-maliyet paylaşım modeli sunamamaktadır. Mevcut analiz yöntemlerinin eksiklikleri, risklere ilişkin sebep-sonuç ilişkilerinin doğru tanımlanamaması, risklerin kendi içindeki ve bütçe artışı ile arasındaki ilişkilerin doğru tanımlanamaması, risk etkileri hesaplanırken projede yer alan taraflar arasındaki risk paylaşım prensiplerinin, sözleşme koşullarının ve risk yönetim stratejilerinin hesaplara doğrudan dahil edilememesi olarak sıralanabilir. Bu tezin amacı, bu eksikliklerin ortadan kaldırıldığı bir modelleme ve simülasyon platformu geliştirilmesidir. Platform aracılığıyla, tamamlanmış projelere ait bilgilerle oluşturulan risk olay belleğini kullanarak proje riskleri ve maliyet artışlarının tahmin edilmesi, sözleşme koşulları ile tarafların kısa ve uzun vadedeki beklentilerinin de dikkate alınarak proje katılımcıları arasındaki risk-maliyet paylaşım sürecinin simüle edilmesi ve tarafların üstleneceği ekstra maliyet tutarlarının belirlenmesi mümkün olmaktadır. Platform çıktıları literatür bulguları ile karşılaştırılmış, gerçek proje bilgileri kullanılarak test edilmiş ve platformun kullanılabilirliğini ve güvenilirliği kanıtlanmıştır.

Anahtar Kelimeler: yapım mühendisliği ve yönetimi, risk yönetimi, uzlaşma, talep yönetimi, çok aracılı sistemler

To my beloved family

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LIST OF ABBREVIATION

A_E	:	The loss of the Employee in case of rejecting an offer
A_O	:	The loss of the Employer in case of rejecting an offer
b	:	Possibility of Loss in Case of a Dispute by not Accepting the Incoming Offer in Zeuthen Theorem and Loss by Time/ Work in Hicks Theorem
BATNA	:	Best Alternative to Negotiated Agreement
CI	:	Critical items
CBR	:	Case Base Reasoning
E	:	Employee
FIDIC	:	International Federation of Consulting Engineers
FIPA	:	Foundation for Intelligent Physical Agents
GUI	:	Graphical User Interface
IEEE	:	Institute of Electrical and Electronics Engineers
JADE	:	Java Agent Development Framework
LoC	:	Level of Confidence
O	:	Employer
MAS	:	Multi Agent System
N	:	Number of Negotiation Rounds
PMBoK	:	Project Management Book of Knowledge
PRAM	:	Project Risk Analysis and Management Methodology
RAMP	:	Risk Analysis and Management for Projects Methodology
RC	:	Risk Consequence
RE	:	Risk Event
R1	:	Adverse Changes
R2	:	Unexpected Events

S	:	Salary
SEM	:	Structural Equation Modelling
t	:	Time Limitation Factor
Uaa	:	Utility of Agent with his Offer
Uao	:	Utility of Agent with Opponent Offer
Uc	:	Utility of Agent at Conflict
UML	:	Unified Modelling Language
V1	:	Vulnerability Factors Influencing the Probability of Risk Occurrence
V2	:	Vulnerability Factors Influencing Manageability of Risk
V3	:	Vulnerability Factors Influencing the Impact of Risk Events
Y_E	:	Share of Employee
Y_O	:	Share of Employer

CHAPTER 1

INTRODUCTION

This chapter presents an overview of the thesis by providing information on research background, problems being address, aim and objectives, contribution of the thesis, and its structure.

1.1 Research Background

Construction is described as a collaborative teamwork of project parties, who have different interests, functions, and objectives but share a common goal for successful completion of the project. The unpleasant changes in the projects objectives (i.e. delays and cost overruns) are generally allied to risks, which are inherent to the complex, dynamic and multiparty nature of construction projects (Levin, 1998). Disputes and claims are considered to "be a way of life" for construction projects to deal with the inevitable consequences of these risks.

Management of construction claims is one of the biggest tasks of contractors in today's challenging business environment (Ren et al., 2001). Although there are several researches focusing on the prevention and resolution of claims, there is still a continuous rise in the number of disputes. According to the American Arbitration Association annual reports published between 2001 and 2014, there is an increasing trend in the number and value of construction claims, which lead to delays, necessitate litigation, and eventually damage business relationships. This fact makes risk management one of the critical factors in international construction projects and directs researches to focus on the integrated decision support systems and information technologies for the success of risk management systems.

Risk management is a concept involving a set of activities such as the systematic identification of the risks, analysis of the impact of these risks on the project, development of risk finance and control strategies, preparation of management plans and revision of management plans based on the investigation of the problems occurring during the project-life. The risk management studies within the construction management literature can be grouped under 4 categories (Dikmen et al., 2004): Development of conceptual models specific to the construction projects, identification of the risks specific to different project conditions such as contract type, country conditions, etc., application of current risk identification analysis tools to case studies and development of decision support systems to aid risk management in companies. In recent years, research has mainly focused on the integrated decision support systems and the importance of the information technology for the success of risk management has begun to be stressed. Risks should to be accurately identified and the possible impacts of these risks on the project should be properly analyzed in order to develop proper strategies to manage the claims.

The basic procedures for handling claims include identification, documentation, delay and cost analysis, pricing, presentation, and negotiation for amicable settlement (Levin, 1998). Within this context, it is very important to model the risks accurately and to define their impacts on project objectives systematically. The evaluation of defined risks should be handled through contractual clauses, documents, rights and own characteristics of the parties to reach a satisfied settlement.

Negotiation is accepted as the initial attempt to solve the claim, before the application of other disputes resolution methods (i.e. litigation, arbitration, etc.), as negotiation helps to sustain amicable relationship between parties (Ren et al., 2003) and avoid the risk of extra cost and unfavourable outcomes (Zeleznikow, 2002). The studies aiming to improve the efficiency of negotiation process can be categorized into two: the studies focusing on improving the human aspects containing planning negotiation, preparing required documentation, adopting proper strategies (Smith, 1992; Zack, 1994) and the studies focusing on usage of information technologies and artificial intelligence models to help in saving time and money in dispute resolution process (Sycara, 1990; Rosenschein and Zlotkin, 1994). For a successful negotiation, the choice of proper background theory and principles which can form the basic rules of the process, as well as the selection of adequate information technology which can facilitate the process are essential.

To sum up, following proper risk management principles and applying a well-structured negotiation route are the key factors for successful claim resolution.

1.2 Problem Statement

While all these researches are providing valuable bases for risk management and negotiation, they have some shortcomings.

Problems in current risk related studies may be listed as the inability in properly identification of risks and inability in formulizing the cause-effect relation between risks for investigation of their consequences.

As risk analysis and response generation are performed considering the pre-defined risks, risk identification is accepted to be the most critical step in risk management (Al-Bahar and Crandall, 1990). However, risk identification is not an easy task as construction projects usually involve a high level of uncertainty, vagueness, complexity and vulnerability to both internal and external conditions. To combine and improve the previous studies, the risks within a project should be evaluated by considering the cause-and-effect relationships among them which will lead to a network form rather than a one-way hierarchical structure.

Although, there are several reference frameworks such as RISKMAN agreed by the European Community (Carter et al. 1994), Project Risk Analysis and Management Methodology (PRAM) acquainted by the Association of Project Managers (Chapman, 1997), Risk Analysis and Management for Projects Methodology (RAMP) endorsed by PMBoK (2000) that provide a systematic approach for risk management, it is clear that their success in practice depends on the risk-related information (such as likelihood of risk, potential impact, risk allocation between the parties etc.) fed into the system. Success of risk models that are used to predict project outcomes under different scenarios also depends on identified risk factors, their interrelations and risk propagation patterns. As pointed out by several researches (such as Tah and Carr, 2001; Gusmão and Moura, 2006; Dikmen et al., 2008a), one of the major shortcomings of the mentioned reference frameworks and risk models is the lack of a common vocabulary. Poor definition of risk and patterns of risk propagation in a project decrease the reliability of risk models that are constructed to simulate project outcomes under different risk occurrence scenarios.

While negotiation is accepted as a basic survival tool for project managers to deal with adverse impacts of risks on project objectives, claim negotiations are usually conducted unproductively. The reasons of inefficiency can be listed as inability in incorporating the legal and personal preferences of the parties in process and incompetency in providing an integrated model through adequate information technology.

In literature, several researches emphasize that the result of the negotiation is highly influenced by the information embedded to the process by the negotiating parties. Smith (1992) and Levin (1998) emphasize the value of getting enough evidence to support claimed items, defining areas of possible zone of agreement, focusing on a reasonable financial goal while protecting the good relations with the opponent and finally listening to the other side and being ready to make concessions in reaching a settlement. However, in previously developed automated systems, the dispute settlement and decision making process solely depends on statistical methods, where many variables of the real negotiation and case specific information sources are ignored.

Moreover, most of the proposed automated negotiation systems are beneficial for a single party in order to evaluate and compare alternative decisions. On the other hand, construction negotiations involve multiple parties, having different backgrounds and objectives, with a series of their actions and counteractions. Involvement of several parties makes multi agent systems a proper method for the modelling of simulation. Multi agent system is a rapidly growing information technology that aims to model the real world through agents representing real entities, which need to contact with each other to reach assigned goals. While the existing multi agent claim negotiation models (Peña-Mora and Wang, 1998; Ren et al., 2001) provide a good basis for the improvement of the previous automated model, they also suffer from the above mentioned limitation. These models mainly rely on various rule-based reasoning techniques such as game theories, Bayesian-Nash equilibrium, and behavioural orientated approaches. However, none of the models have attempted to incorporate the information related with claim case and negotiating construction parties into the model. For the proper sharing of risks, the characteristics of construction industry need to be deeply investigated and the factors influencing the decision making process should be included in a multi agent risk sharing negotiation models.

1.3 Aim and Objective

The main goal of this thesis is to develop a comprehensive model by integrating the risk management principles, negotiation theories and multi agent technology for the simulation of the risk analysis and risk allocation processes between project parties to achieve an acceptable responsibility distribution.

To reach this goal, the specific objectives are set as the development of a common vocabulary for risk identification that addresses the shortcomings of current risk identification system, integration of risk event database in risk impact determination stage, search of elements driving negotiation process in construction claim management environment and the automation of the system under a single multi agent platform.

- The previous studies in risk management are extended by presenting an ontology for relating risk-related concepts with cost overrun. Risk identification is undertaken by considering causal relations between various risk sources (namely, risk paths) and sources of vulnerability that interfere with these paths. The overall aim in constructing an ontology is to give an agreed terminology by specifying the risk concepts as well as relationships between these concepts, that is computationally utilizable, sharable, and reusable by human or machines.

- Through the usage of ontological structure, it is aimed to provide a database system that represents risk event histories of international construction projects and construct a risk model for estimation of cost overrun. In the system, the risk paths happened throughout the project and vulnerability sources are targeted to be identified through the integration of a similarity model that uses the formalized risk event histories. The outcomes of the model mainly related with the cost overrun and the driving risk items will form the basis of the risk allocation negotiations to be undertaken between project parties.

- Another aim of the study is to analyse the characteristics of the negotiations undertaken in the construction industry and to figure out the main factors influencing the negotiation process. The intention is to cooperate the critical factors into the automated negotiation model for a more realistic application.

- With the goal of reaching a comprehensive risk analysis and risk allocation model, the above described entities are targeted to be combined under a multi agent model. Each part of the study will be represented by agents in the model and project parties will negotiate with each other to share the risks through the information taken from other agents.

1.4 Contribution

With this thesis, a more comprehensive risk estimation system with multi agent negotiation model will be presented to have a complete risk allocation and sharing model. The developed system will systematically analyze the risks, estimate cost overrun value and do risk allocation and cost sharing.

The developed system will advance the risk modeling environment and the integration of all important stages under a single multi agent platform makes it possible for contractors to make simulations. It improves the risk identification stage through description of risk paths and risk ontology. It provides a risk event database in determination of risk consequences. It allows the usage of information sources related with contract clauses, causes of the claims and the claim amount during the negotiation process in addition to the issues related with strategy of the parties.

By using the presented model, contractors carrying out international projects will be able to identify risks in a more realistic manner at the start of a project, to estimate their impacts by creating possible risk scenarios, to bid and contract by considering the risk magnitudes and to formulate effective risk management strategies. Since the main reasons of disputes in international construction projects are the poor risk identification and analysis, it is believed that the MAS-based risk estimation, risk allocation and cost sharing environment will increase the success of contractors significantly.

For effective control of project and to formulate proactive dispute management strategies, early knowledge of critical issues and prediction of potential outcomes are essential. As stated by Chou and Lin (2013) “depending on the possible outcomes of a dispute, precautionary measures can be taken proactively when a project is in progress. Additional preparation in preventive actions can be beneficial once the disputes occur by reducing the future efforts, time, and costs of multiple parties during dispute settlement.”

1.5 Disposition

The thesis is composed of eight chapters:

Chapter 2 introduces the background of the research by giving details of concepts related with risk, negotiation and multi agent systems. Chapter 3 presents the research methodology for development of conceptual models through the previous studies as well as motivating interviews. In Chapter 4 and Chapter 5, the conceptual model for risks analyse process and negotiation model are presented, respectively, with their all aspects. In Chapter 6, multi agent model development process that combine the outcome of previous chapters is discussed in detail. Chapter 7 is to show the details of the validation of developed multi agent platform. Finally in Chapter 8, summary of studies done and recommendations for further studies are stated.

CHAPTER 2

RESEARCH BACKGROUND

The model presented within this thesis is formalized through the joint research of several fields, including risk management, cost overrun estimation, risk paths and multi agent system applications. The initial studies made in early stages of this research (Fidan, 2008; Çelenligil, 2010; Eybpoosh, 2010; Karakaş, 2010) already cover the very detailed literature review for these individual fields separately. Therefore, the focus of the literature review within this thesis will be the analysis of the connection between these individual fields as well as the investigation of additional features acting in risk sharing process, in addition to the deep investigation of the dynamics of the dispute resolution systems.

This chapter presents the background of the thesis in three main sections. First section covers the concepts of risks and conflicts and the main challenges of the current systems developed to solve them. The second section is to define the negotiation, its dynamics and influencing parameters in construction industry. In last section, literature review on multi agent systems is given in order to figure out the different approaches toward conflict resolution and negotiation with multi agent systems.

2.1 Construction Project Risks and Conflicts

Cheung et al. (2006) states that conflicts and oppositions are linked with inadequate risk allocation, changes in construction plans, specifications and mistaken information. Unclear documents, late supply of material and equipment, low profit margins, scope changes, improper weather conditions, restricted site access are also listed as examples for the sources of conflicts in construction industry (Semple et al., 1994; Kumaraswamy and Yogeswaran, 1998). Other researches (Harmon, 2003; Levin, 1998; Pulket and Arditi, 2009) add size and duration of the project, complexity and contract documents, poor communication, limited resources, financial constraints, inadequate design, labor issues, and force majeure events as the driving factors for construction disputes. Studies in construction management literature draw attention to the fact that one of the major causes of project failure is the improper handle of these disagreements (Latham, 1994; Merna and Bower, 1997; Egan, 1998).

It is clear that, the unpleasant changes in the projects objectives (i.e. delays and cost overruns) are allied to risks, which are inherent to the complex, dynamic and multiparty nature of construction projects (Levin, 1998; Ren et al., 2001; Kululanga et al., 2001). Hence, risk management is one of the critical factors for the elimination and resolution of construction disputes.

Risk management is a concept involving a set of activities such as the systematic identification of the risks, analysis of the impact of these risks on the project, development of risk finance and risk allocation strategies, preparation of management plans and revision of management plans based on the investigation of the problems occurring during the project-life.

There are several studies in literature focusing on risk management and risk identification (Wideman, 1986; Flanagan and Norman, 1993; Zhi, 1995; Raftery, 1994; Han and Diekmann, 2001; Hastak and Shaked, 2000; Cano and Cruz, 2002). Using these risk breakdown structures, decision-makers may assess the magnitude of different sources of risk and further identify potential risk events that may affect project outcomes. However, in spite of its vital role, most of the current risk management applications are incomplete.

The major problem in risk analysis is that the currently available methods cannot fully reflect the dynamic nature of the construction projects and cannot incorporate the common decision making process of multiple parties. Limitations of the available analysis tools may be listed as the inability in properly formulizing the cause-effect relation of the risks, inability in definition of interrelations among the risks, inability in identification of the probabilities based on the statistical data, inability in incorporating the risk sharing principles between the project participants, contract clauses and risk management strategies directly into the computation of risk impacts. These limitations make the current systems incapable to moderate the conflict resolution and risk sharing process.

To eliminate these shortcomings, a new flowchart for risk consequence analysis is proposed at the early stages of this study (Fidan et al., 2011). In the system, risk factors are suggested to be evaluated by considering the cause-and-effect relationships among the risk factors leading to a network form rather than a one-way hierarchical structure (Dikmen et al., 2007; Tah and Carr, 2000; Han et al., 2008). Through this way, risk models that simulate project performance can be based on risk paths rather than individual risk sources. Moreover, in proposed system, during the identification phase, a critical issue, which is defined as "controllability/manageability" by Dikmen et al. (2007) and "project vulnerability" by Zhang (2007), is considered to characterize the system's influence on risk consequences. A system's vulnerability represents the extent or the capacity to respond or cope with a risk event (Zhang, 2007). Vulnerability and risk assessment are integrated to understand how a project will respond to risk events considering its vulnerability.

There is a consensus in literature regarding the existence of causal relations between risks and necessity to develop risk paths and integrate vulnerability into risk management process (Zhang, 2007; Turner et al., 2003; Busby and Hughes, 2004). The first step of this research is development of a common vocabulary and an ontological structure to explain interrelations between risk sources, risk events, vulnerability, and their consequences. The cost overrun percentage is accepted as the only consequence in the developed model. The correct and more realistic estimation of risks and the value of cost overrun generated due to these risks will help project parties to better analyze their projects and focus on the real reasons of the disputes. The development and validation process of risk and vulnerability ontology is discussed in detailed at Fidan et al. (2011).

2.2 Negotiation in Construction Management

Understanding the risks is one of the crucial stages of coping and mitigating them. The other critical stage in successful mitigation and fairly distribution of the risks and their impacts between participants is the capturing of the dynamics in negotiation process. For this purpose, basis of negotiation process, theories, previous applications and the parameters directing the decision making process of parties in a construction project are investigation in this section of the thesis.

2.2.1 Basic Negotiation Terminology

Negotiation is simply the act people do to get what they need or want from the opponent party. Through negotiation, parties try to find a settlement point, from several options, that is acceptable for both parties (Muthoo, 1999). Either it is formal or informal, oral or written, direct or through mediators, every negotiation has some core elements that should be shaped before starting negotiation (Patton, 2005).

The basic elements of the negotiation are defined as the interest, social motivates of the participants and their interactions by Sycara and Dai (2010). Wohlgezogen and Hirsch (2009) define the negotiation actors, space and moves as the key elements of the negotiation environment. All these elements shape the interactions between parties, their negotiation space and negotiation acts to solve the issue (Figure 2.1).

In literature, there is a widely accepted seven elements theory of negotiation proposed by Fisher and Ury (1981):

1) Interest: A party's basic needs and motivations are named as its interest. The main success criterion in a negotiation is measured by how much extra payment he gets from the opponent (Moffitt and Bordone, 2005).

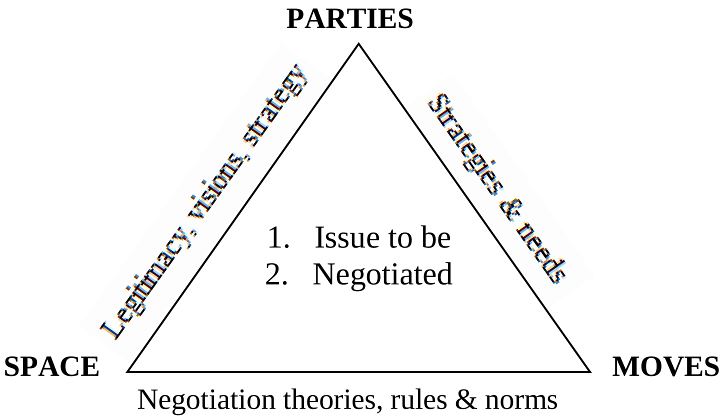

Figure 2.1. Negotiation environment **(**adapted from Wohlgezogen and Hirsch, 2009)

2) Alternatives: Alternative in a negotiation is described as "Plan B" by Fisher and Ury (1991) to be used in case of any disagreement. Therefore, the negotiator shall always compare the incoming offer with the alternative case and try to choose the most beneficial one (Moffitt and Bordone, 2005). Alternative is also known as "BATNA" standing for Best Alternative to Negotiated Agreement.

3) Options: Negotiation is to search an agreement point which is better than BATNA and enough to meet the needs of both parties. Options are the potential agreements points.

4) Legitimacy: Fairness or legitimacy is the governing factor in negotiation. To be persuasive, one should demonstrate to the opponent that the offer is reasonable. For this, external criteria and objective standards shall be used.

5) Commitment: For a successful negotiation, both parties shall commit to act in purpose of reaching an agreement within the time limitations and steps agreed.
6) Relationships: An important variable in the negotiation is the type of the relationship that negotiator wants to build with the opponent (Moffitt and Bordone, 2005). Type of the relationship between parties entails how easily the agreement can be reached.

7) Communication: Communication is the process where parties discuss and handle the remaining six elements of the negotiation. Communication is to explain ideas and gather information about the opponent.

Seven elements theory helps to understand the components of negotiation more clearly. While all these elements are mostly mixed with each other, seven elements concept provides a way to separate and focus each one, which is essential for development of an automated system. Though literature reviews, these variables in international construction projects will be investigated to figure out the core factors acting in the negotiation process.

Each negotiation has a start point (target), an end (agreement or disagreement) and a series of steps (offers) in between. To direct these steps and to change the progress when it becomes ineffective, negotiators should be conscious of its characteristics and steps (Leritz, 1994).

The factors influencing the decisions of the Client and Contractor are essential in order to understand their target values and minimum amounts that they can accept. Contractor's target is to compensate almost all of his losses, while Client wants to complete the project with minimum additional payments. Negotiation will take place only if there is possible agreement zone between the defined positions (Figure 2.2).

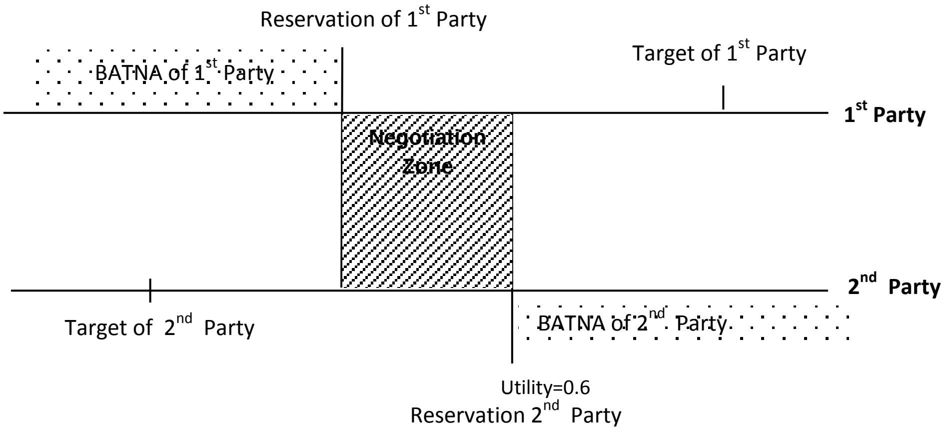

Figure 2.2. Negotiation Terms

2.2.1.1 Target Value

The highest amount that a party aimed to take from the negotiation is named as Target and it will be the initial proposal of the parties (Raiffa, 1982). Calculation of initial offer is very important as the parties can not suggest any more improvement during the negotiation process. As it is not a very easy task to determine the target value, in literature either consultation of a well-qualified third party or a well-structured system is recommended (Veenen, 2011).

2.2.1.2 Reservation Value

The minimum value that a party is willing to accept in negotiation is named as reservation value. Reservation value is closely related with Best Alternative to Negotiated Agreement (BATNA) (Mnookin et al., 2000), as the values under this limit is named as BATNA (Fisher et al., 1991; Richardson and Metcalfe, 2002). BATNA defines what will happen in case of a conflict in negotiation, therefore Parties need to know their BATNA to assess whether the incoming offer is acceptable or not (Fisher et al., 1991). Defining reservation point before the negotiation is a key factor in successful negotiation. By determining reservation value, parties are protecting themselves from accepting an unfavorable option during negotiation (Veenen, 2011).

Having a well-developed BATNA determination process for dispute resolution applications is essential to reach a satisfactory solution, especially while using automated resolution tools (Lodder and Zeleznikow, 2005). While there are several studies emphasizing the importance of BATNA determination in negotiation, there is not a structured model in literature (Veenen, 2011). Within this thesis, a system for BATNA / reservation value estimation will be presented, to direct the claim negotiations, based on the characteristics of international construction industry.

2.2.1.3 Concession

The range between the target point and reservation point is the concession range. The bargaining tactics should be to start with the target and make concessions to reach an agreement. Under reservation point, negotiator should not accept any offer and put an end to negotiation.

2.2.1.4 Negotiation zone

The area between the reservation values of the negotiating parties is called as negotiation zone or bargaining range. Negotiation zone provides a range of options rather than a single agreement point, which increases the probability of finding a solution that fits the specific needs and expectations of parties in negotiation (Veenen, 2011). The negotiation starts with the target offer from a party and takes places within the negotiation zone. This area will be positive or negative. If it is negative there will be no settlement unless one or both the parties changes reservation points.

2.2.1.5 Utility

The objectives of the parties are usually specified as “utility”, or more explicitly “profit” (Wilkes, 2008). The utility of a negotiator at his target point is highest, and utility decreases by coming closer to reservation point. Utility functions are the mathematical representations of the user preferences that are useful in development of automated systems. In this study, linear utility curves will be used for simplicity.

2.2.2 Negotiation Theories

In literature, there are several studies approaching negotiation from different point of views, including game theory, behaviour theory, artificial intelligent theories, reasoning base theories (Ren et al., 2003; Kersten, 1997; Jenning et al., 2001). Within these approaches game theory is selected as the core of the model within this thesis.

Game theory is known to be a branch of economics and primarily focuses on the exchange of offers between agents, each have fixed choices with inclusive knowledge of all achievable solutions, through some predefined interaction rules (Rahwan et al., 2004). Almost all of the theories related with bargaining and decision making processes are founded on game theory (Brams, 1990). It intends to define the tactical relation between intelligent decision making agents. It focuses on the decision making principles and strategies necessary for the processes that require the involvement and joint decision of two or more independent parties (Bacharach and Lawer, 1981). Game theory is known to propose an influential mechanism for studying and arranging strategic interaction among self-interested computational agents and for automated negotiation (Von Neumann and Morgenstern, 1944).

In game theory, it is assumed that agents can characterize their preferences by considering all possible outcomes and they have perfect computational rationality (Rahwan et al., 2004; Hsairi et al., 2008). The abilities, alternatives and preferences of the parties are assumed to be definite at the initial stage of negotiation and will remain same throughout the negotiation process (Kersten, 1997; Ren at al., 2003). As game theory makes possible to proper analyze of the case and selection of well-defined solutions, it is used widely in evaluation of various scenarios and actions of parties (Kersten, 1997).

Due to the limitations of the game theory in formalizing the complex human impact, its application area is limited. Game theory is originated from economic theories. On the other hand, behavior theory has roots from psychology, sociology and organizational theories. Behavior theory supports the existence of a learning mechanism in the negotiation (Ren et al., 2003). In economic theory, a more dynamic model is tried to be developed which takes the value offer and counteroffers into account. In contrary to game theory, in behavior theory it is not necessary to learn all the strategies of the opponent party (Ren et al., 2003). The weakness of behavior theories is that they give the main focus on the modeling of the act multiple parties instead of the negotiation process itself, which makes the researches to apart from the main target and focus on secondary issues (Zartman, 1977).

2.2.3 Concession Protocols in Negotiation

Wooldridge and Jennings (1999) defines the protocol in negotiations as the rules directing the interaction of parties. These rules cover the number of parties involved in the negotiation, main stages (like accepting the offer or ending it), progresses thoughout negotiation (like sending new offer), the acts of parties (like who will make the decision, who will send the message, etc.).

By considering these rules, the negotiation protocols are grouped in three main categories in literature: contract net protocol, monotonic concession protocol and fish market protocol (Conry et al., 1988; Davis and Smith, 1983; Sycara, 1989). The properties of these protocols are summarized in Table 2.1.

Table 2.1 Comparison of Negotiation Protocols

Protocol	**Time dependency**	**Attendees**	**Process**	**Flexibility**	**Valid actions**
Contract net protocol	No	One person can contact with several person	One stage tender	No new party can be involved to the process	Only accept or reject
Monotonic concession protocol	Yes	One-to-one interaction	Negotiation	No new party can be involved to the process	A revised offer will be given in case of rejection
Fish market protocol	Yes	Several person can contact with one person	Dutch auction	A new party can be involved to the process	Actions will be defined according to several tactics

Monotonic concession process gives possibility to interactive negotiation. Until reaching a settlement, negotiating parties need to make concession over their offers. In case parties are not willingness to concede, the negotiation will end with conflict (Ren et al., 2003).

2.2.4 Bargaining Strategies

The bargaining strategy to be used by the parties is playing an important role in determination of how much compromise a party shall make from his target. In literature, the most widely used strategies are Zeuthen Strategy and Hicks Strategy.

In Zeuthen (1930) and Hicks (1932) strategies, employee (E) and employer (O) negotiate on salary (S). Parties can get their rights if they can agree about the sharing percentages, represented by Y_E and Y_O. However, if the parties could not reach an agreement, they will make concession in proportion to “b” value. In Zeuthen strategy, “b” means the possibility of loss in case of a dispute by not accepting the incoming offer. In Hicks model, “b” represents the loss by time/ work in suspension period. The loss of the parties in case of rejecting an offer is represented as A_E and A_O (Usher, 2003). The relation between these parameters is as follows:

$$(1)\ Y_e = b*A_E \text{ and } Y_o = b*A_o$$

$$(2)\ b*A_E + b*A_o = S$$

As being the mostly widely used strategy, in Zeuthen parties determine the highest possibility of disagreement that they can accept and the party with the less risk acceptance level makes concession (Young, 1975). In negotiation process, parties are willingness to give as less concession as possible until reaching the agreement. Hicks model is important as it considers loss by time in his model. However, Hicks does not provide a clear mathematic representation of how the concession amount will be calculated.

For negotiation process, the description of the risk behavior of the parties and making concession are essential. Zeuthen strategy provides a suitable model in calculating the concession amount for this study. Moreover, it can be improved by including the time limitation factor as recommended by the Hicks model.

2.2.5 Factors Influencing the Decision Making Process of Construction Parties

This section focuses on the characteristics and dynamics of negotiations in construction domain. Analyzing construction domain specific features is essential for the appropriate selection and successful application of bargaining strategy and theory.

In literature, there are several studies focusing on how to regulate interactions between parties to reduce and solve claims and disputes through negotiation, arbitration or mediation. Traditionally, mediation and arbitration are used when the struggle increases, the interrelationships between the parties get stressed and position starts to get hardener (Kassab et al., 2010). On the other hand, negotiation is preferred as the initial attempt to solve the conflict, since it is economical, time saving and it helps to sustain amicable relationship between parties (Ren, 2003).

Negotiation is a very common process in human affairs and negotiation models are developed for various field including economics (e.g. Conlin and Furusawa, 2000; Kim, 1996), organizational behaviour (e.g. De Dreu, 2003; Lewicki et al., 1992), and computer sciences (e.g. Kraus, 1997). While the aim of researches on negotiation in social sciences is to discover the factors influencing the negotiation among people, in economics and computer sciences researches try to provide mathematical formulations to develop systems calculating optimal solutions to be use in real life (Sycara and Dai, 2010). In construction management literature negotiation is also a remarkable research area with the aim to combine the previous findings of social sciences and economics.

Kassab et al. (2006) demonstrates a system based on graph model to investigate the strategic interaction between owner and contractor for conflict resolution. Kilian and Gibson (2005) analyze the records of previous litigation cases and extract the historical data to evaluate the current litigation cases. Pulket and

Arditi (2009) presents a prediction model for construction litigation based on previous court cases. Ren et al. (2003) focus on automated negotiation to solve claims and Kassab et al. (2010) presents a decision support system help in resolving construction disputes.

Previous studies in literature are investigated deeply to figure out the most critical factors directing the decision making process in construction domain in case of a conflict. The identified factors will be used in development of the risk sharing model aimed in this thesis. The common elements to characterize a dispute are recognized as contract, participants, their options, and their preferences.

Contract is accepted as the starting point for interpretation of a dispute, as construction project disputes are content-specific and highly influenced by the conditions of contract (Cheung et al., 2011; Cheung and Pang, 2013). However, it is a fact that contract clauses are not always straightforward and will not be enough solely to solve each dispute. Appropriately developed contract and equitable risk distribution has been proposed as dispute prevention measures (Treacy, 1995; Fisher, 1988; Jannadia et al., 2000), on the other hand, vagueness in risk allocation in contract clauses is directly linked with a potential dispute. As all possible problematic situations cannot be predicted in contracting stage of a project, the parties will have different perceptions on the arising situation and its interpretation stated in contract clauses. Moreover, the contract clauses will not be fair or both parties will have failed to perform some of their contractual responsibilities (Mitropoulos and Howell, 2001).

While contract characterizes the basic options of the participants, the decision about how to handle unclear risk allocations in contract is controlled by the power of the negotiators (i.e. the negotiator will either ask the opponent to compensate the related cost overrun or will try to handle on his own). For that reason, the power of the parties in negotiation is as influential as contract conditions. Rate of these parameters may influence the probability of winning the negotiation.

Even if the contractor is contractually right, he will not gain any negotiation power unless he has objective supportive documents to prove his legitimacy. Document based information enables the parties to evaluate the merits of each case and to determine which party should take the responsibility of the case (Kangari, 1995). Several researches emphasize that the result of the negotiation is highly influenced by the information embedded to the process by the negotiating parties and the one who supports cases with accurate records will be the superior. Smith (1992) and Levin (1998) emphasize the importance of getting enough evidence to support claimed items, defining areas of possible zone of agreement, focusing on a reasonable financial goal while protecting the good relations with the opponent and finally listening to the other side and being ready to make concessions in reaching a settlement. Time schedules, photographs, daily records, schedule of values and original estimates are listed as the key evidences to be used in any conflict (Kangari, 1995, Hegazy et al., 2005, Dossick and Schunk, 2007). Pickavance (2001) and Zeleznikow (2002) also accept the determination of facts of a case and the careful exploration of legal documents with the aim of finding legal arguments as one of the essentials of claim negotiation.

For the resolution of the dispute, the direct involvement of client and contractor to the negotiation are also essential (Russell, 1990). The relations between these parties and perceptions about each other affect the process (Mitropoulos and Howell, 2001). Kassab et al. (2010) also mention defining own preferences, entering own understanding of the other parties' opinion are necessary to analyze the possible position of the other parties and decide on the actions in a dispute.

Previous operational relationship between parties, degree of reliance on price consideration of contractor, incentive for client to settle, possibility of using the same contractor in future projects are the variables influencing the decisions of Client (Cheung et. Al, 2000; Cheung et. Al, 2010). Russell and Jaselskis (1992) emphasized element of trust as a factor affecting dispute resolution. Contract reputation and continuity of existing project are also accepted as the items shaping the acceptance criteria of an offer in a conflict (Kassab et al., 2010). Contractor's need for the work, having concurrent projects with same Client and expectation of future works will influence elimination criteria of Contractor (Russell, 1990; Thompson and Perry, 1992).

The effectiveness of the process depends heavily on the competence and experience of the negotiators (Goldberg et al., 1992; Brown and Marriott, 1999). Claim consciousness; claim experience and negotiation skills of contractor are listed to be important by Cheung et. al (2000) and Cheung et. al (2010). Client's experience, degree of involvement of client in running of project and negotiation skill of the client's team will let client to better analyze the disputed issues (Russell and Jaselskis, 1992; Cheung et al., 2000; Cheung et al., 2010).

Time pressure is listed as another factor influencing process, which is defined as the desire to reach agreement quickly (Pruitt, 1981). In negotiation, deadlines are established to create time pressure as a tactic to make the opponent concede more (Carnevale, 1986). Time pressure makes the negotiators act less competitive, and accept agreement more quickly (Mosterd and Rutte, 2000).

Through the findings of literature review, the variables are defined to shape the options and preferences of participants and to assess their power degree in the construction dispute resolution process (Table 2.2 and Table 2.3) Increase power makes the parties to gain more in negotiation.

Table 2.2 List of Power Variables for Contractor with Their References

Variable	**Reference**
Experience in claim management	Currie and Dorris (1986), Goldberg et al. (1992), Brown and Marriott (1999), Cheung et. al (2000) and Cheung et. al (2010).
Claim consciousness	Currie and Dorris (1986), Brown and Marriott (1999), Cheung et. al (2000) and Cheung et. al (2010).
Negotiation skills	Goldberg et al. (1992), Brown and Marriott (1999), Cheung et. al (2000) and Cheung et. al (2010).
Keeping good relations	Russell (1990), Thompson and Perry (1992) Kometa et al. (1994, 1995), Mitropoulos and Howell 2001, Cheung et. al (2000) and Cheung et. al (2010)
Previous working relationship	Kometa et al. (1994, 1995), Mitropoulos and Howell 2001, Cheung et. al (2000) and Cheung et. al (2010)
Future expectations	Kometa et al. (1994, 1995), Mitropoulos and Howell 2001, Cheung et. al (2000) and Cheung et. al (2010)
Bureaucratic ease to negotiate	Cheung et. al (2000) and Cheung et. al (2010)
Existence of supportive document	Kangari (1995), Hegazy et al. (2005), Dissick and Schunk (2007)
Knowledge of client	Mitropoulos and Howell (2001), Kassab et al. (2010)
Time limitation	Pruitt (1981), Carnevale (1986), Mosterd and Rutte (2000)
Clarity of contract documents	Mitropoulos and Howell (2001), Russell and Jaselskis (1992), Currie and Dorris (1986), Scott and Harris (2004), Cheung et al. (2011), Cheung and Pang (2013)
Contractual obligations	Mitropoulos and Howell (2001), Russell and Jaselskis (1992), Currie and Dorris (1986), Scott and Harris (2004), Cheung et al. (2011), Cheung and Pang (2013)

Table 2.3 List of Power Variables for Client with Their References

Variable	**Reference**
Trust to contractor	Kometa *et al.* (1994, 1995), Russell and Jaselskis (1992), Russell and Jaselskis (1992)
Technical and managerial capability	Russell and Jaselskis (1992), Goldberg et al. (1992), Brown and Marriott (1999), Cheung et. al (2000) and Cheung et. al (2010).
knowledge on contract and project	Russell and Jaselskis (1992), Goldberg et al. (1992), Brown and Marriott (1999), Cheung et. al (2000) and Cheung et. al (2010).
Experience	Brown and Marriott (1999), Cheung et. al (2000) and Cheung et. al (2010).
Time	Pruitt (1981), Carnevale (1986), Mosterd and Rutte (2000)
Contract	Mitropoulos and Howell (2001), Russell and Jaselskis (1992), Currie and Dorris (1986), Scott and Harris (2004), Cheung et al. (2011), Cheung and Pang (2013)

2.3 Multi Agent Systems

Multi agent system (MAS), as a branch of distributed artificial intelligence, advances on design and implementation of systems that involve intelligent agents contacting with each other to reach assigned goals (Weiss, 1999). The power of MAS comes from the division of work to agents and the cooperation of these agents, as 'the most basic technique for tackling any large and complex problem is to divide it into smaller, more manageable chunks'' (Booch, 1994). By decomposing a task into smaller subtasks and assigning them to different agents, a complete solution to the original task will be obtained through partial solutions made by the agents among their own interests and goals (Stone 2000).

Objects, agents, existing relations and performed operations are the main units of MAS and among these elements; agent is accepted as the most crucial one (Ferber, 1999). Ferber (1999) defines agent as “a physical or virtual entity that can act, perceive its environment and communicate with others; agent is autonomous and has skills to achieve its goals and tendencies”. In MAS, multiple agents are flexible, have self-directed action in the situated environment (Wooldridge, 1997). The agents are autonomous computer systems that can react to changes in their environment and are able to change their environment with their actions (Jennings and Wooldridge, 1995). Agents are interconnected to function in a manner exceeding the capability of any singular agent (Nwana, 1996).

According to Wooldridge and Jennings (1995), there are four key concepts related with agent: agents are autonomous (operate without the direct participation of humans), agents have social ability (connect with other agents), agents are reactive (perceive their environment and respond changes in a timely manner) and agents are pro-active (exhibit goal-directed behavior by taking initiative).

The main goal of MAS is to create systems that make separately developed agents work together and function beyond their own abilities within the system in order to use their knowledge to solve the problem (Vlassis, 2003). When the problem occurs, the agents collaborate to ensure that the interdependencies are properly managed through coordination and negotiation in order to reach at a mutual agreement regarding their beliefs, goals, or plans (Ren et al., 2003; El-adaway and Kandil, 2010).

2.3.1 Multi Agent Systems in Negotiation

Negotiation is a joint decision making process that aims to find some compromise or consensus between two or more parties through a process of defining contradictory demands/offers and reaching agreement by concession making or searching new alternatives (Pruitt, 1981; Amgoud et al., 2007). In their research, Ren et al. (2003) emphasizes that although negotiation has a vital role in averting disputes among project participants in case of claims; the complex nature of interactions, the dissimilar background and expectation of parties result in inefficient claim negotiations. In construction management literature, several automated negotiation systems (such as Arditi and Patel, 1989; Ngee et al., 1997; Ren et al., 2003; Peña-Mora and Wang, 1998) have been proposed in order to save time and human resources allocated to finalize this process. While most of the previously developed tools are beneficial for a single party in order to evaluate and compare alternative decisions and rank the alternatives from most preferred to least; construction disputes involve multiple parties with a series of actions and counteractions instead of a just one final decision (Kassab et al., 2010). Therefore, within the existing attempts that aim to design automated negotiation structure, multi agent systems have gain a special attention.

As the nature of the construction projects, multiple project participants need to get together to perform various construction activities including solving complex problems. Such a complex interactive environment, that necessitates the joint workout of different entities, can successfully be modeled through interoperating and collaborating multi agent systems (El-adaway and Kandil, 2010).

MAS are used in solving problems and simulating environments where the data, expertise, and control are distributed, such as supply chain management, planning, claim management, design and dispute resolution. Molinero and

Nunez (2011) propose a methodology to simulate every small task of a site-work with a multi-agent system. Klein et al. (2012) present a multi agent system that can interact with occupants to provide suggestions for reducing building energy consumption. Several researches (such as Maher et al. ,2005; Rosenman et al., 2007 and Fenves et al., 1994) provide multi agent solutions focusing on resolution of collaborative design problems. An application of multi agent system for real-time monitoring and planning on construction sites is proposed by Zhang et al. (2009). Some researchers (such as Sycara, 1990; Rosenschein and Zlotkin, 1994; Kraus et al., 1998; Faratin, 2000) proposed agent negotiation systems and some researchers (such as Peña-Mora and Wang, 1998; Ren et al., 2003; El-adaway and Kandil, 2010; Karakaş, 2013) presented dispute and claim negotiation models.

Within the existing attempts to develop multi agent negotiation systems, the ones related with dispute and claim negotiation, i.e. CONVINCER developed by Pena-Mora and Wang (1998), MASCOT by Ren et al. (2001), MASCOR by El-adaway and Kandil (2009) and cost sharing model developed by Karakaş et al. (2013) are vital for this study as they are the outstanding studies focusing on the construction claim resolution.

CONVINCER, based on game and negotiation theory, proposes a collaborative negotiation methodology to solve conflicts in construction industry. In the developed system, construction industry is accepted as a non-zero sum game where all parties share the profit and the rational agents, having complete information on payoff and utility functions, are designed to maximize their own utilities (Pena-Mora and Wang, 1998). This structure permits the optimal settlement and optimal alternative selection to find the mutual interest immediately. In the formation of the agents’ payoff functions, main construction characteristics (i.e. self-interested groups, domain dependent knowledge, and strategy influenced process) are considered and this system proposes a reasonable contribution to resolve the claims. MASCOT is a multi-agent claim negotiation system, where agents act in place of project parties (Ren et al., 2003). The basic theory applied to construct the system is a combination of game theory, economic theory and behaviour theory. Agents try to reach settlement through making offers, counter offers and concessions. A more comprehensive structure than CONVINCER is formalized by adapting Bayesian-Nash equilibrium strategies in settlement process and Zeuthen's model in concession mechanism. In this model, while the rational agents have fixed and predetermined strategies, they have ability to learn and update their beliefs about the opponents' reservation values throughout the negotiation process. El-adaway and Kandil (2009) proposes MASCOR, which is an arbitration system for construction claims that focuses on the outcomes of precedent dispute cases to generate legal arguments to overcome some of the limitations of the previous studies. The proposed system uses the similarities/ differences between current and precedent cases to make agents defence their positions. While using facts and outcomes of precedent cases is a superior contribution to dispute resolution, the main focus is the arbitration process instead of negotiation.

As an early attempt for negotiation model to be used in this study, a prototype multi agent negotiation model is developed by Karakaş et al. (2013). The designed model is to simulate the cooperation between parties about the sharing of cost overruns. The developed prototype differs from its stimulants by: (1) estimating the main input variables of the negotiation (i.e. first-offer and reservation values) based on the contract conditions and features of the negotiation environment (2) using a separate contract agent to represent the contract conditions, (3) providing users three different negotiation protocols (time-dependent concession, Zeuthen's strategy, and Zeuthen's strategy with Bayesian learning) to model the process. The prototype MAS model presented is constructed to understand the negotiation process between the parties. Thus, it assumes that cost overruns are known and does not consider the risk paths.

The main lessons learned through the prototype multi agent risk and cost sharing platform are as follows (Karakaş et al., 2013).

- The borders of the negotiation (mainly lowest acceptable offer) highly influences the outcome of negotiation, therefore more importance should be given to the factors determining the value of lowest acceptable (reservation) offer rather than the negotiation protocol.
- Through the performance analysis of different negotiation protocols, of these three protocols Zeuthen's strategy is recommended to be used in modelling as it takes into consideration the utilities of the agents and provides stability.

The finding and recommendations gathered through prototype study form the basis of the multi agent system to be developed within this thesis.

CHAPTER 3

RESEARCH METHODOLOGY

To achieve the objectives of the thesis, various research methods are adopted including interviews, conceptual modelling and system evaluation. This chapter will give brief information about these research steps and their outcomes.

In first part of this chapter, the outcomes motivating interviews, conducted to understand and combine the application of literature findings in construction industry, are discussed. The conclusions derived from motivating interviews and literature reviews are listed in next section of this chapter. Finally, the structure of the conceptual models are introduced.

3.1 Motivating Interviews

Following the literature review, in order to investigate the previously developed multi agent claim negotiation models and their effectiveness, motivating interviews are performed with domain expert Interviews are conducted to better understand the needs and must haves of automated claim negotiation systems. By combining the findings of literature review and motivating interviews, the model for risk sharing platform is developed.

To better comprehend claim negotiation process, interviews are made with four experts, having excessive experience as negotiator and arbitrator in international construction projects (Table 3.1). The aim of the interviews was to observe the main properties and main elements of the claim negotiation process in order to decide on the conceptual framework of the automated system.

Table 3.1 Experts Consulted for Motivating Interviews

Expert	Position and Expertise	Year of Experience
A	Lawyer, expert in international arbitration cases of construction projects	35 years
B	Consultant, expert in international construction projects management	19 years
C	Professor at University, expert in construction management branch	24 years
D	Professor at University, expert in construction management branch	19 years

During the interviews first, the reasons of the claims are questioned and all the experts are likeminded that the reasons can be associated with the risks and vulnerabilities inherent to the projects. Therefore, they believe in that the sharing of cost overrun should be founded on the risk allocation scheme among main project participants, which can be determined through examination of contract clauses and risk events happened. Providing objective appearing rationale, concerning contract and risk paths, to support claims is considered as the core of the negotiation activity. One other essential issue, discussed by experts, is the strategy used by the parties. The factors determining the strategy such as future expectations, the relation, legitimacy levels, time limitations, willingness to cooperate etc. are listed as important criterion shaping the negotiation process. Experts also believe in that instead of negotiating each item separately, the contractors should prefer to negotiate as a package to use the advantage of generating alternative packages and increasing the possibility of agreement. The questions also contains the ones related with the ranges of the parties, such as whether the negotiation ranges (i.e. reservation value, aspiration value, BATNA) shall be determined prior to the negotiation (pre-defined and fixed) or they can be shaped during the negotiation process (changeable). The experts are likeminded that the values, in the mind of Contractor, are approximately determined during the claim preparation stage. However, when there is not enough information, the Client values will be shaped through the negotiation process according to the information gathered from the environment and other parties.

3.2 Findings of Literature Review and Motivating Interviews

The main conclusions, derived from the interviews and literature reviews, point out some major shortcomings of previous studies and hence, recommend some strategies to develop their performance:

1. Negotiation is the initial attempt to solve the conflicts and it is the mostly preferred conflict resolution mechanism by all project parties. Therefore, the intended system should also focus on negotiation instead of other alternative mechanisms. Instead of focusing on the mathematical rules in process, the main features in analyze of the case and effecting the strategy are more crucial.

2. As the main focus is the formalization of negotiation process with its all aspects, game theory is selected to be the appropriate negotiation theory. Game theory is a widely accepted theory which is simple in application.

Parties are rational, know the preferences of each other and through concessions they can reach most acceptable point.

3. Monotonic concession protocol is the most appropriate system reflecting the properties of construction negotiations. Parties made concessions in their offers to reach an agreement.

4. All the experts mentioned the absolute necessity of using related contract clauses and facts to solve these claims in a fair and realistic way. Each conflict item should be evaluated based on the quality of supportive document. However, in previously developed systems like CONVINCER the dispute settlement process is based on classical game and negotiation theory, where many variables of the real negotiation are ignored and decision making process solely depends on statistical methods. While MASCOT is a more sophisticated one, the proposals are made without considering the facts and legal documents, which prevents reasoning the fairness of the results (El-adaway and Kandil, 2009). Therefore, this study recommends the usage of information sources related with contract clauses, causes of the claims and the claim amount during the negotiation process in addition to the issues related with strategy of the parties.

5. In previously developed models, like MASCOT, the claim item, the target and minimum acceptable offers are directly entered by the user to the system. However, experts stated that estimating these values is not an easy task. To support the users, the developed system covers variables to assess the negotiation power of the parties. As the negotiation to be performed within the scope of this thesis aims to reach a mutually satisfying resolution, the preferences and acceptance criteria's of both parties shall be considered in the model. Through literature review several parameters influencing the decisions of the parties are collected

and with the help of experts these items are combined and simplified. Time limitation, liability given in contract, quality of supportive documents, relations with client, experience and belief about knowledge of client are decided to be the determiners for Contractor. For Client, contract clauses, time flexibility, project reputation and trust to Contractor are selected as the main variables.

6. Most negotiations take place in the context of an ongoing relationship where it is important to carry on each negotiation in a smoother and efficient way. Similarly in construction projects, experts mentioned that, contractor and client are contractually linked with each other to complete the aimed project. Each team had to be rational and avoid being frustrated and offended. Therefore, the personality of negotiators and their negotiation attitudes are accepted to be balanced and be smooth, and not considered as a parameter in the model.

7. Both CONVINCER and MASCOT have an analytical approach to claim negotiation by using game theoretic techniques and they are mostly based on the exchange of offers according to some interaction rule. In game theoretic applications, agents are accepted to have complete and predefined preferences over negotiation issues with full awareness of all possible solutions, besides the agents are allowed to exchange only proposals related with the claim amount. When the construction business practices are concerned, the approach is acceptable as the parties mostly negotiate cost data and try to settle on an amount that will satisfy both parties. However, estimation of the cost overrun and its reasons are also critical. In order to make the system more realistic, the additions to the cost determination stage of those systems should be made. Therefore; before applying game theory or economic theory for modelling the negotiation process, a system supporting risk evaluation and cost of risk should be added to claim negotiation system.

8. Based on the previous multi agent system studies and prototype system developed by Karakaş (2010), the main features of the multi agent system to be developed within this thesis are decided as follows:

    - System shall be a closed environment, which consists of a fixed number of entities with a common target.
    - Agents shall have complete information on utility functions
    - The rational agents shall have fixed and predetermined strategies. During negotiation process they will try to choose the best offer through their defined strategies.
    - Agents will be self-motivated, in other words they shall act only by considering their interests and try to get the maximum from the negotiation
    - Agents shall act in place of construction project parties and for formation of the agents' utility functions, main construction characteristics and factors influencing construction parties decisions shall be considered
    - A separate contract agent shall provide data about the contract conditions
    - Zeuthen's strategy shall be used in concession mechanism
    - Facts and outcomes of precedent project cases shall be used to estimate cost overrun value and critical risk factors

3.3 Conceptual Model Development

The literature review and the motivating interviews conducted with domain experts form the basis of framework for the sharing of risk and cost overrun among project participants.

In literature review, it is seen that imperative studies have been conducted to manage risks, understand and automate negotiations in construction industry. However, through interviews it is realized that, most of these studies are not comprehensive enough to capture the process as a whole and to guide the sector practitioners to understand all influential factors of this process.

To improve the initial studies, this thesis is aimed to propose a framework for handling risk identification, a tool for risk consequence analysis and a platform for negotiations on sharing risk impacts (Figure 3.1).

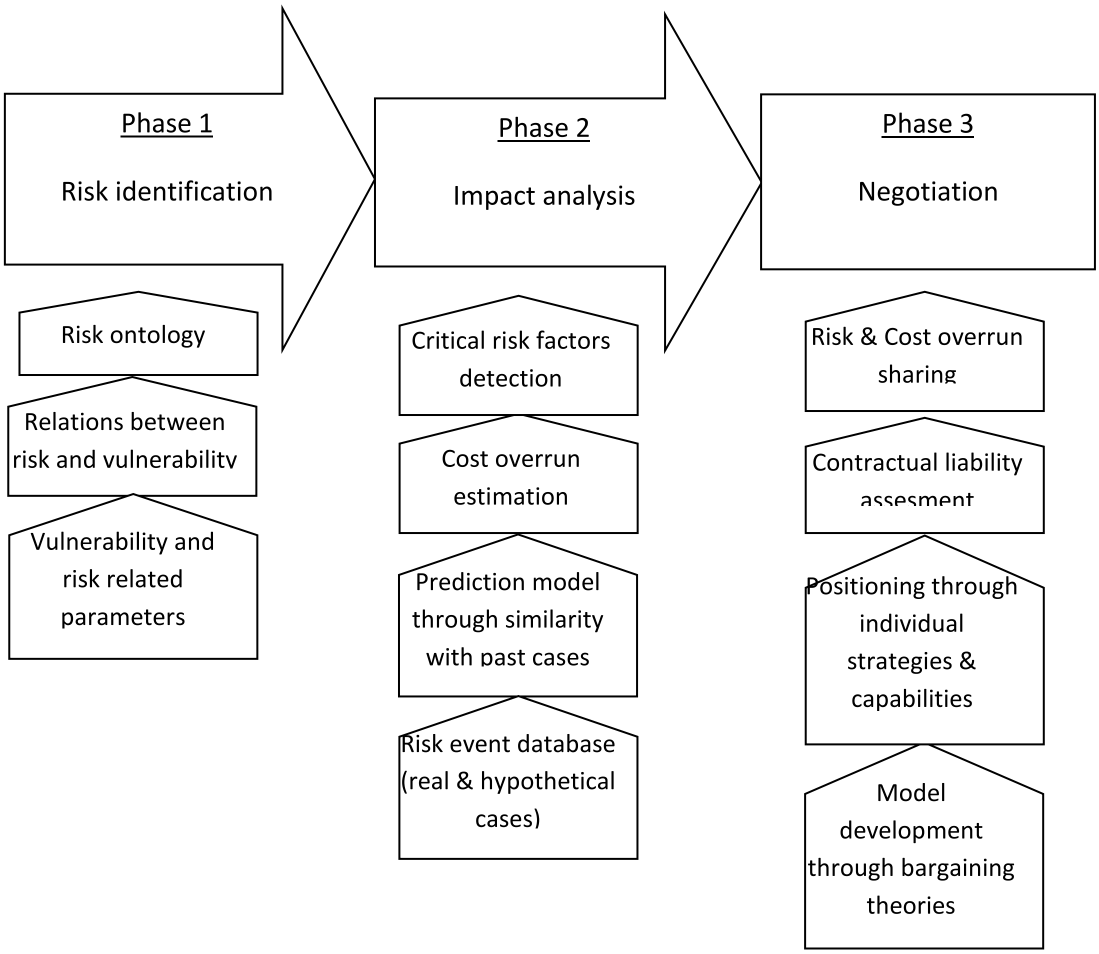

Figure 3.1 Main Phases of Risk Sharing Platform

Risk identification and risk impact analysis stages is discussed under third chapter of the thesis, negotiation and its sub stages are detailed in forth chapter of the thesis.

This thesis is the final outcome of a research project which aims to develop a Multi-Agent System (MAS) to simulate risk management, cost overrun estimation and cost sharing negotiations. The conceptual models developed for risk and negotiation phases of the platform aims to combine and improve the initial findings of this research project.

In initial stages of the research project, firstly, a conceptual risk and vulnerability framework is constructed (Dikmen et al., 2009) to overcome the basic limitations of risk management process. Vulnerability and risk concepts were then identified, documented and validated in an ontology-based database (Fidan et al., 2011). The risk event histories are further used to construct a Case Based Reasoning (CBR) cost overrun prediction model for international construction projects (Çelenligil, 2010). Structural Equation Modeling (SEM) technique was used to estimate the impact of each risk on cost overrun (Eybpoosh et al., 2011). A prototype MAS negotiation platform is developed to simulate the negotiation process between parties about sharing of cost overrun (Karakaş et al, 2013).

The initial studies related with risk, vulnerability and risk impact prediction will form the basis of the conceptual model to be developed for risk assessment phase. Then, the findings of literature and motivating interviews will be incorporated to develop the conceptual model for negotiation phase. The initial attempt made for MAS negotiation model will be the starting point for the risk allocation platform aimed.

The concluding outcome of the thesis will be the multi agent system that combines and automates the developed conceptual models under a single structure. The improved risk management process will be simulate in the multi agent platform and the outcomes will be used as the basic inputs of the negotiation process to be conducted among project parties to achieve an acceptable degree of risk and cost sharing. The risk paths, vulnerability sources and contract conditions throughout the project will shape the negotiation preferences and ranges of the parties, together with the long-term and short-term expectations, contract conditions and their attitudes. Finally, contractor and client will interact with each other to reach a proper risk allocation and cost overrun sharing. Finally, developed platform will be evaluated and tested to understand its compliance with literature findings and real cases.

CHAPTER 4

CONCEPTUAL MODEL: RISK ASSESMENT PHASE

The first section of this chapter demonstrates the details of starting step named as the risk and vulnerability identification. Risk and vulnerability parameters, the relations among these parameters and the ontological structure to be used in further stages of the study will be covered under this heading. In second section, the method used to analyze the impact of the risk parameters is demonstrated. For impact analysis, initially a risk event database is developed by using the ontological structure. Then, through prediction model, the cost overrun rate and the impact rate of each risk parameter are estimated. Finally, the importance weight of each risk parameter on cost overrun generation is investigated.

4.1 Risk Identification Stage: Risk Ontology

4.1.1 Illustrative Case Studies

Before the construction of ontology, case studies were conducted to question the validity of risk and vulnerability paths in construction projects. To identify a general risk and vulnerability propagation pattern in construction projects, seven completed international construction projects were investigated (Fidan et al., 2011). The Turkish contractors that are actively working in the international construction market were selected, and experts from these companies were interviewed. All the experts interviewed have at least 10 years of experience in managerial positions in the international construction industry. The cases were chosen so that different country, company, and project-related features, and consequently different risk paths, could be observed.

Detailed information about the projects was collected through meetings with experts, each lasting for 1–1.5 h. For each project, the participants were requested to give some information about the risk events they faced, reasons for risk events, the triggering factors that affected the occurrence of these events, response strategies used by the company, and their consequences for on project success, particularly cost. A cognitive map of each expert's statements about each case study project was drawn and submitted for the expert's approval. The key concepts raised by the interviewees were identified as potential elements of the risk and vulnerability ontology. More information about the case study projects and associated maps can be found in Dikmen et al. (2008a, 2008b). The aim of the case studies was not to produce a comprehensive set of factors that may lead to cost overrun in construction projects but to identify a general structure that can guide us while developing the risk and vulnerability ontology. The identified structure that explains the causal relations is depicted in Figure 4.1.

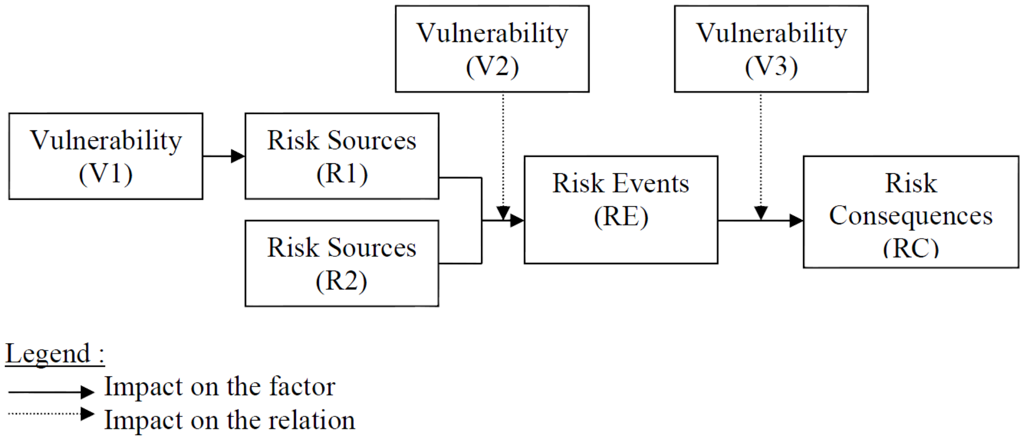

Figure 4.1 Risk and Vulnerability Paths

As it can be seen from Figure 4.1, case studies demonstrated that vulnerability factors may affect different stages of the risk realization process. Some vulnerability parameters (V1) influence the probability of risk occurrence. For instance, intensive construction activity within the region triggers the risk of unavailability of local labor and material. Some vulnerability factors (V2) are about manageability of risk. For example, if the company has a strong local partner, the impact of change in local regulations (R1) may be less because the partner may communicate effectively with the local authorities and manage the situation. Vulnerabilities (V3) may also influence the impact of risk events on project success. For instance, the implication of the increase in the quantity of work (RE) differs depending on whether the payment type is unit-price or lump-sum. A risk path example taken from the case studies is given in Figure 4.2.

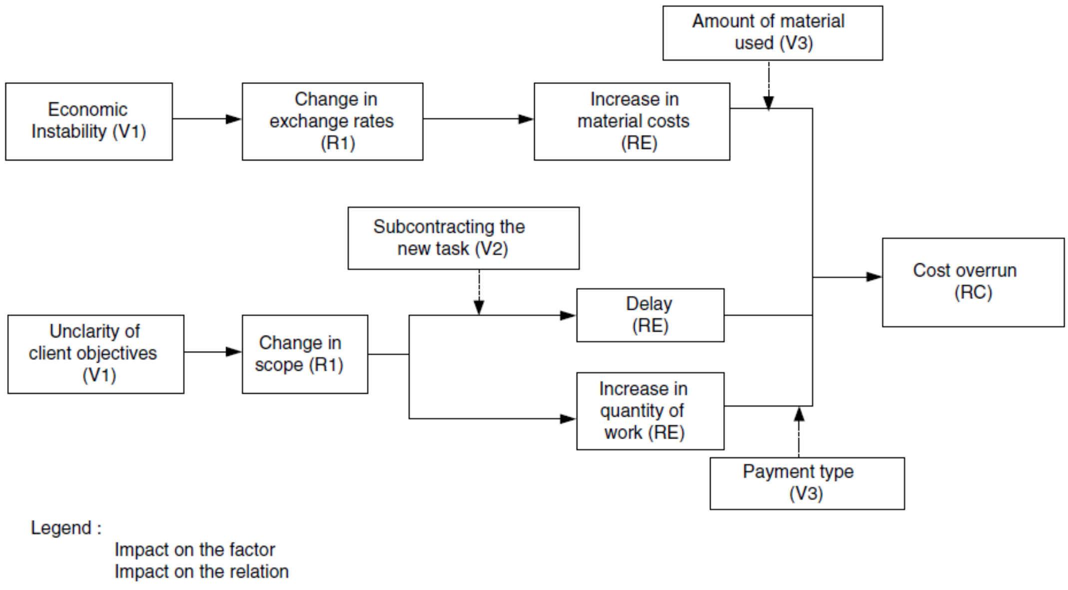

Figure 4.2 An example to risk paths

4.1.2 Ontology Development

Ontology development included five main stages: specification (determination of the scope), conceptualization (the collection and organization of the relevant domain concepts to be included in the ontology), formalization (the representation of knowledge in a formal way), implementation (converting the formalized knowledge into a machine-comprehensible ontology language) and evaluation (validating the completeness and the generality of the ontology) (Fernandez-Lopez et al, 1997). Figure 4.3 demonstrates the ontology development process and supporting activities of each step. An iterative development process and interviews with domain experts are preferred in this stage of the study, as suggested by various researchers (eg. Gruber, 1993; McCray and Bodenreider, 2002).

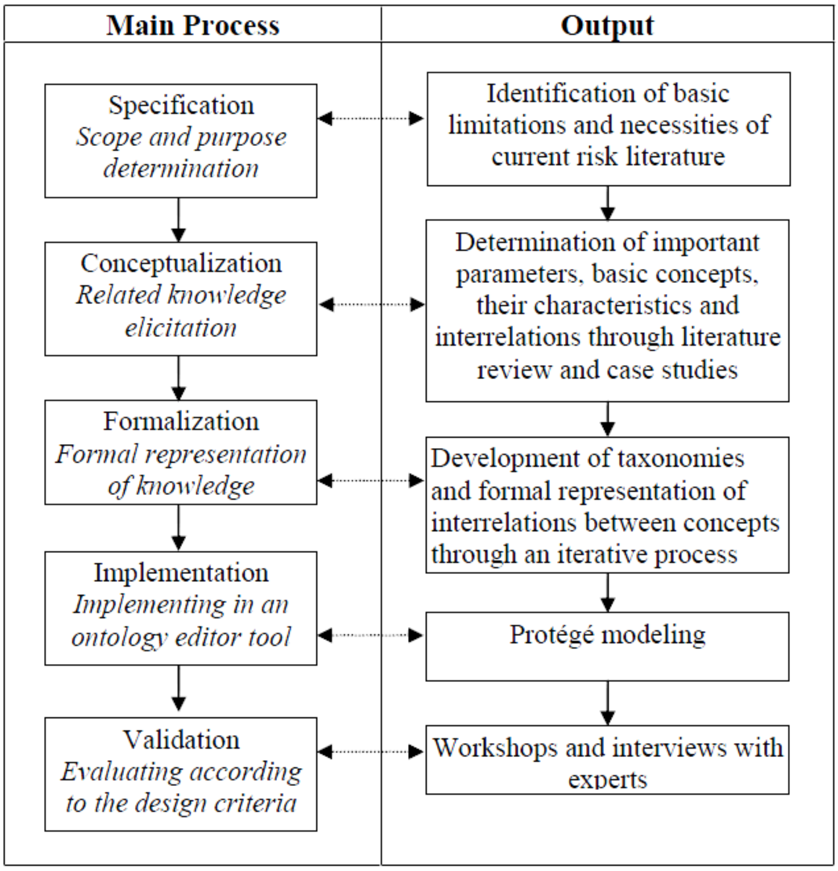

Figure 4.3 Ontology development process

The specification step was carried out by elicitation of risk-related knowledge by a detailed literature review as well as the interviews carried out with domain experts. Referring to the findings of the literature survey, an initial model was developed which included 250 concepts, 170 and 80 of which were related with "vulnerability" and "risk", respectively. An interview form that includes these concepts and their interrelations was designed and interviews were conducted with experts about the validity of the concepts. The experts were requested to comment on comprehensiveness of the list of concepts as well as the correctness of the relationships. They were also asked if they could provide the necessary data about real projects to fill in the form so that risk event histories of projects can be captured. Domain experts are the experts interviewed during initial case studies and 3 more experts from the industry all having managerial positions in international construction companies. In the light of expert suggestions, some of the parameters were rephrased and grouped. For example, factors such as inflation rate, tax rate, exchange rate in the country were found to be important to characterize the economic conditions of the country during the literature survey. During the interviews, it was realized that the specific values of these rates are important for cost estimation. However, for estimating cost overrun, the stability of those rates is more important than their specific values. Therefore, those parameters were grouped under the same heading and named as the "stability of economic conditions". Final version of the model contains 150 concepts related with risk and vulnerability.

In the conceptualization stage, to obtain a more structured organization of the collected data, concepts (classes) were organized into a superclass-subclass hierarchy, which is also known as taxonomy. Taxonomy helps to bring substantial order to elements in a model, presents categorization of the elements for human interpretation and helps reuse and integration of tasks (Welty and Guarino, 2001). Noy (1997) considers this stage as one of the most difficult activities in ontology design, as it involves not only a subjective representation of the world, but also the representation of how people see this world and how they categorize things in their minds.

In the formalization stage, an iterative development process was used to produce a mature ontology that is suitable for real world implementation. A semi-computable absolute representation of the ontology was obtained by illustrating the concepts, their attributes, and restrictions of these attributes as well as interrelations between the concepts. The formalized knowledge was converted into Protégé frame-based representation which is an ontology development tool from Stanford University. Protégé permits integration of (1) the modeling of ontology of classes describing a particular subject, (2) the creation of a knowledge-acquisition tool for collecting knowledge, (3) the entering of specific instances of data and creation of a knowledge base, and (4) the execution of applications. The utmost advantage of the Protégé is that, with knowledge model developed through Protégé, one can also facilitate conformance to the Open Knowledge Base Connectivity protocol for accessing knowledge bases stored in knowledge representation systems (Protégé 2000 User Guide). During the implementation process, classes (identified concepts), their slots (defined attributes of concepts), the facets (restrictions of the attributes), instances (the actual data in the system) and relations between classes were entered into the software.

Finally in the validation stage, the developed ontology was tested in terms of its level of completeness, generality and effectiveness. These metrics were verified through interactive workshops and interviews with domain experts.

Through this process, the risk and vulnerability related concepts, their attributes and relations are defined.

4.1.3 Risk-Related Concepts in the Ontology

Risk is accepted as an event which may cause deviation in pre-defined objectives, if it occurs (PMBoK, 2000). Due to its vital role in understanding the underlying reasons of cost overruns, identification of risks involve identification of risk paths from its source to event rather than particular risk items in the ontology. Risk factors are categorized according to their places within the risk paths such as risk sources,

risk events or risk consequences. If a factor has a potential to cause a risk event/problem, it is identified as a risk source. On the other hand, if it is a result of a risk event, it is named as a risk consequence. The taxonomy of the risk related concepts are given in Figure 4.4.

4.1.4 Vulnerability Related Concepts

In spite of the fact that all companies and projects are exposed to risk, some characteristics of firms and projects will influence the impact of risk in the event of its occurrence (Khattab et al., 2007). The term “vulnerability” is used to explain inborn characteristics of a system that exist within systems independently of external hazards and depend on an organization’s capability to manage risks. Similar to risk related concepts, all vulnerability parameters are gathered by investigation of real cases in addition to literature findings. As Twigg (2001) mentioned, in order to understand the factors that increase a system’s vulnerability, one should diverge from the risk event itself and consider a set of influences. For international construction projects the factors related with the contract, company, project and project participants come together to create these influencing factors. In this research, the identified vulnerability sources within a project system are categorized considering their places within a risk path as follows: robustness sources, resilience sources and sensitivity sources.

The taxonomy of the vulnerability related topics included in the ontology are given Figure 4.5.

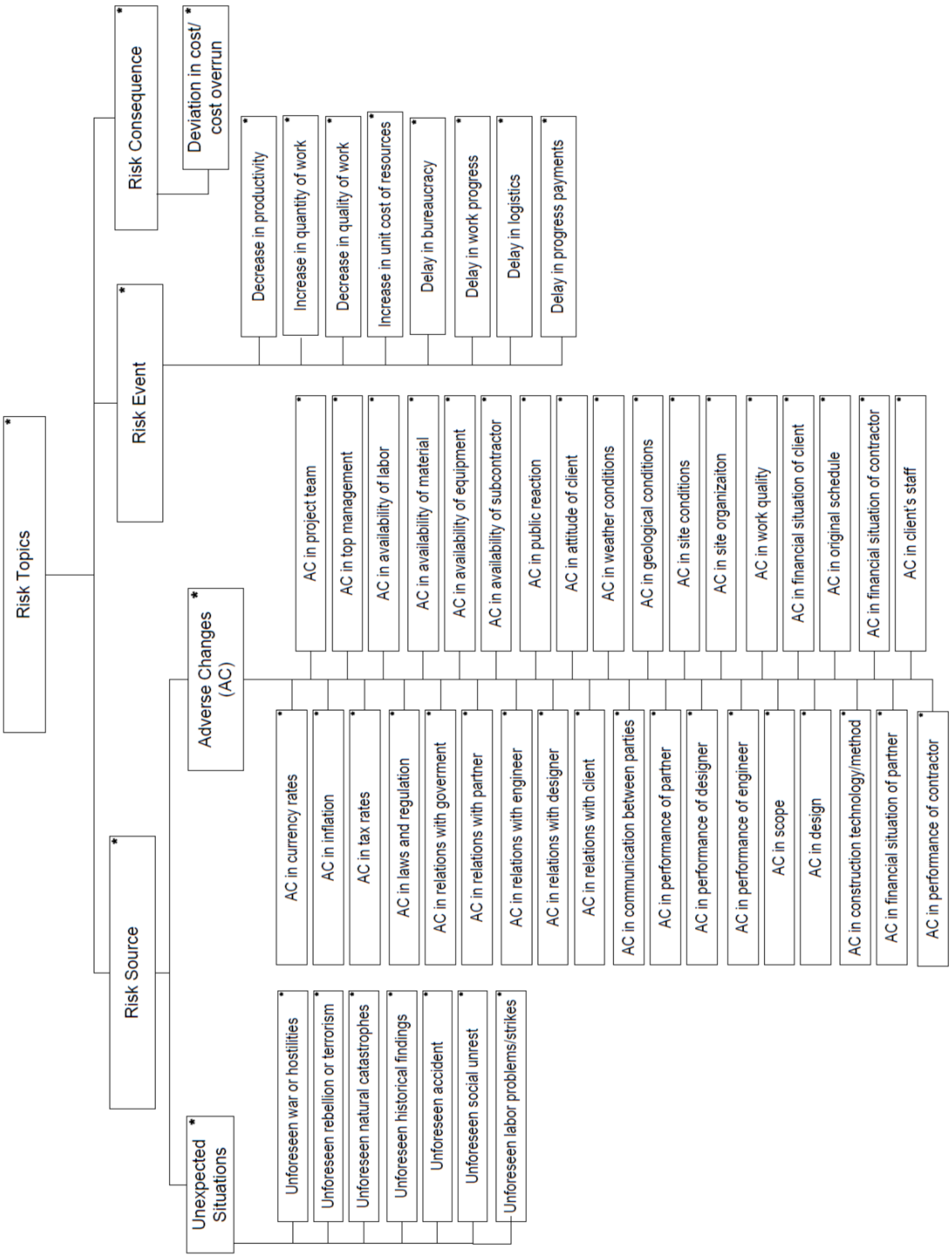

Figure 4.4 Taxonomy of risk related concepts

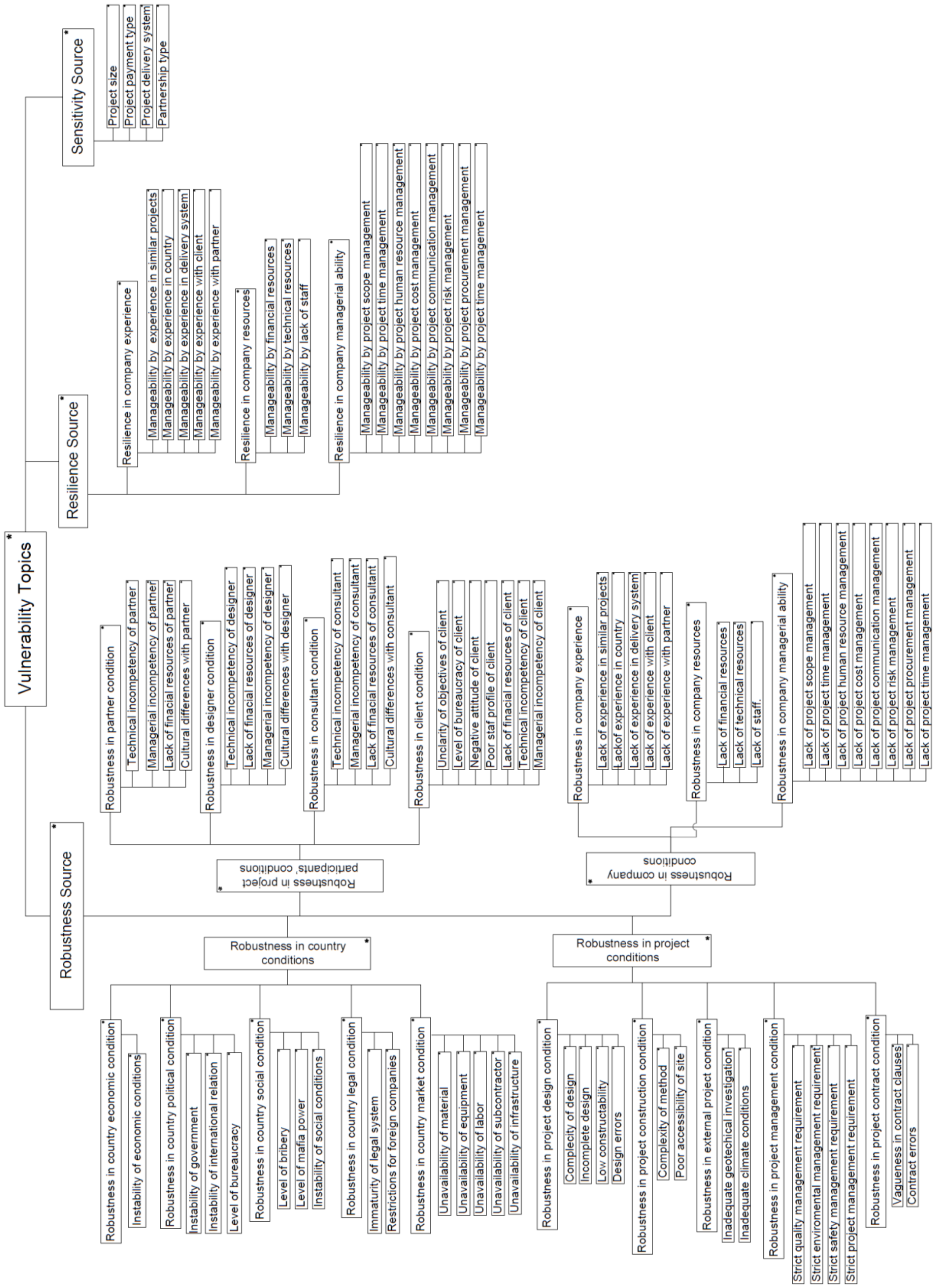

Figure 4.5 Taxonomy of vulnerability related concepts

4.1.5 Relationships among Classes

While defining the concepts of risk and vulnerability, their interrelations are also investigated deeply to formalize the most probable risk paths. In the identification of the relations case studies play a vital role, as there is not any analogous study that focuses on the details of integration of vulnerability and risk in the literature.

Four main relations are distinguished between concepts in the ontological model: association relationships (e.g. project has zero or more risk and vulnerability sources), navigable association relationships (e.g. robustness source influences the risk source and risk source causes risk event), aggregation relationship (e.g. risk is composed of source, event and consequence), and inheritance relationship (e.g. robustness source, resilience source and sensitivity source are the child classes of vulnerability source class).

The causal relations (Figure 4.6) between vulnerability and risk which lead to cost overrun can be summarized as follows:

Every project inevitably has certain risks and vulnerability sources. Robustness source, resilience source and sensitivity source concepts are the child classes of these vulnerability sources. Robustness source (indicating weaknesses that exist within the project) influences the occurrence of adverse changes in the project. The magnitude of robustness sources influences the magnitude of adverse changes. Adverse change and unexpected situations are the child classes of the risk source. Both adverse changes and unexpected situations lead to risk events in a project. However, the strength of the causal relation between adverse change and risk event is influenced by the resilience parameters existing in the project. Resilience source influences the manageability level of the adverse change, and hence the impact level of the adverse change on risk event varies with respect to level of manageability. Risk events lead to risk consequence, which is cost overrun. However, as the sensitivity sources influence the impact level of a risk event, the magnitude of risk event do not directly affect the magnitude of risk consequence. Risk consequence indicates a deviation from original cost of a project therefore it is accepted to influence the project.

It should be noted that all factors under a specific category are not necessarily affected by all factors given under the preceding category. For example, all of the factors under “adverse change” are not influenced by all “robustness source” parameters. There are individual relations among the factors that lead to a number of risk-vulnerability paths, some of which coincide whereas others are completely independent

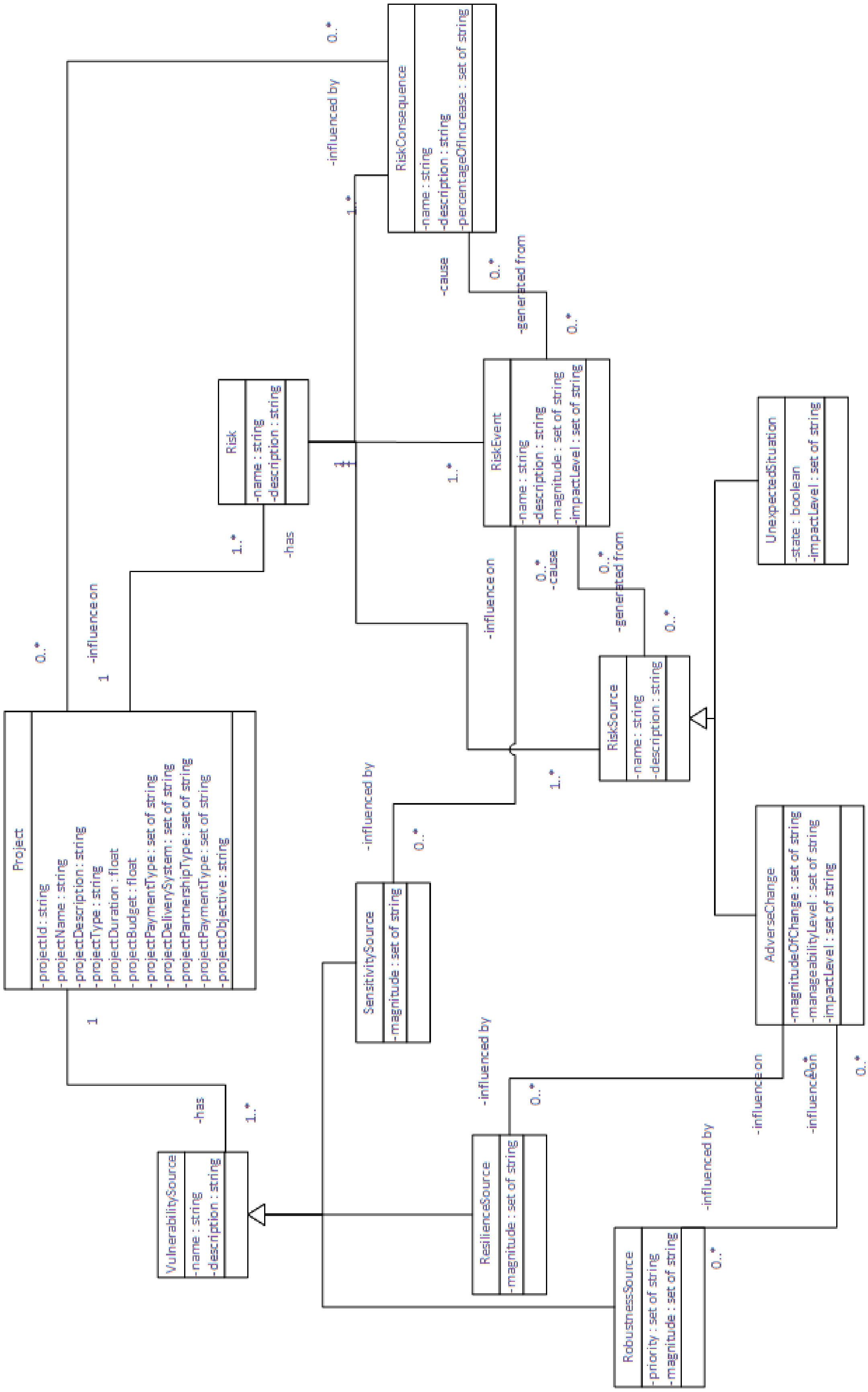

Figure 4.6 Data model for the risk and vulnerability ontology.

4.1.6 Validation of Ontology

In the first stage of the study, it is aimed to develop an ontology for relating risk and vulnerability with cost overrun. The quality attributes of the ontology are defined as generality, completeness, and effectiveness. Ontology can be considered complete if it covers all necessary attribute to relate risk and vulnerability with cost overrun. It can be accepted as general if it has the ability to represent a variety of cases (Staub-French et al., 2003; El-Diraby et al., 2005). Effectiveness of the ontology is ensured if it is capable of helping estimators to generate realistic estimates with high degree of confidence. Table 4.1 summarizes the quality attributes and their metrics used during the validation process.

To assess whether the ontology complies with the predefined quality attributes, an interactive workshop and interviews with industry practitioners were performed. At the start of the workshop, each expert was given necessary information about a real international construction project. The general information about the projects included the role of the company in the project, country name, project type, estimated budget, duration, payment type, and project delivery system. The projects were selected so that different project types and countries having different risk and vulnerability levels could be considered during the workshop. After the experts studied their individual cases, a questionnaire including 14 questions was administered to them. To answer the questions, the experts had to follow a three step process, which is summarized as follows:

Table 4.1 Metrics for ontology validation

Questions	Attribute	Metric
Does the ontology cover all attributes that are necessary to relate risk and vulnerability with cost overrun?	Completeness	Number of concepts/attributes identified by the experts that are not within the ontology
		Subjective rating of experts about "completeness of the ontology"
Does the ontology improve the cost overrun estimation process?	Effectiveness	Comparative error in cost overrun estimates (with and without ontology)
		Subjective rating about level of confidence in cost overrun estimates (with and without ontology)
		Number of critical attributes considered during cost overrun estimation (with and without ontology)
Does the ontology have the ability to represent a variety of cases?	Generality	Number of cases that can be represented by the ontology with respect to different project size, types, delivery systems, countries, contract types, payment types and different company roles

1. The experts were requested to specify the information about the project that would be required to estimate cost overrun (e.g., does the company have enough staff? How is the relation between contractor and client?). This step was important for assessing completeness of the ontology. Because the metric of completeness is defined as the number of factors that are found important by the experts but not included within the ontology, information about potential missing attributes was sought. After the experts were provided with the additional information they requested, they were asked to identify the possible risk events of the given project. The answers of the experts to this question were critical for checking the completeness of the risk-related attributes in the ontology. Finally, experts were asked to estimate the cost overrun in the project by using any method they suggested or using their expert judgment only,

without utilizing any methods. Also, they were asked about their level of confidence in these estimates.

2. The ontology, including all of its parameters and their interrelations, was given to the experts. The main concepts related with risk and vulnerability and possible interrelations among the concepts were explained. In addition to the general information about their projects, in this case, the magnitudes of all robustness sources that describe the initial conditions of the project were also provided to each expert. They were again asked to estimate cost overrun, but this time by considering the ontological relations and the parameters given in the ontology. They were also asked to indicate their level of confidence in these estimates. Because the projects were already completed and actual cost overrun values were known, the errors in cost overrun percentages estimated when using and not using the ontology were calculated. The comparative error and confidence levels as stated by the respondents were intended to check the effectiveness of the ontology.

3. In the last step, as they got familiar with the ontology, the experts were asked about potential improvements to the developed ontology. They were asked how familiar they were with the terms used in the ontology, whether the used terminology was appropriate or not, and whether the ontology covered the main domains of construction management for cost overrun estimation. Finally, they were asked to specify whether there were any items that were not covered by the ontology. The answers to these questions were intended to assess completeness.

In second stage of the validation, interviews with 25 industry practitioners from 18 different construction companies were conducted. Interviews were intended to test whether the information about completed projects having different characteristics, such as project type, country, project delivery system, contract, and payment type, could be represented by the ontology. The variety of the cases that could be represented by the ontology would be used as an indicator of its generality. Using the ontology, practitioners were asked to indicate the magnitude of risk and vulnerability associated with the already completed projects and state the actual cost overrun percentages. Moreover, practitioners were asked to denote additional factors that could be included in the ontology. Table 4.2 shows the results of interactive workshop.

Table 4.2 Summary of the workshop findings

Cases	**Actual Values**	**Without using the ontology**			**Using the ontology**		
	Cost overrun percentage	CI	Cost overrun estimate	LoC	CI	Cost overrun estimate	LoC
Case 1	50%	14	23%	3	20	29%	4
Case 2	25%	9	14%	3	12	21%	4
Case 3	10%	6	15%	2	7	10%	3
Case 4	30%	9	14%	3	14	24%	4
Case 5	75%	12	45%	3	29	45%	3
Case 6	65%	8	35%	2	15	45%	4

Note: CI indicates the number of critical factors that are considered while estimating cost overrun, whereas LoC indicates the level of confidence of the experts about their estimates using a Likert scale of 1-very low to 5-very high

In Table 4.2, actual cost overrun percentages and the number of critical factors that led to cost overrun in the already completed projects are presented. Actual cost overrun percentage is calculated by dividing the difference between the actual cost and the estimated budget by the estimated budget. None of the experts preferred to use a "method," but they used their intuition and judgment to estimate cost overrun. The average absolute error with respect to actual values is around 20% without using the ontology, whereas it is 14% when the ontology is used. The average level of confidence of the experts about their estimates also increases to 3.7 from 2.7 when they use the ontological representation. Moreover, the average number of critical factors that were considered by the experts during cost overrun estimation was 16 and 10 with and without using ontology, respectively. These results demonstrate that the ontology helps users to make better predictions, consider a higher number of factors that may lead to cost overrun, and increase their confidence in estimates, which points out the effectiveness of the ontology. However, it is important to note that the ontology in its current form is not expected to be used for cost overrun estimation; rather, it will constitute the basis of a case-based reasoning prediction model. The most significant indicators of its effectiveness are believed to be metrics related to improvement in the cost overrun estimation process (particularly, a higher number of factors that can be considered during cost overrun estimation and increased confidence of estimators) rather than the accuracy of estimates. The experts who participated in the workshop indicated that the terminology used in the ontology is appropriate and that the ontology is complete enough to relate risk and vulnerability with cost overrun (with an average rating of 4.7 out of 5). During the cost estimation exercise that did not use the ontology, none of the experts required information about factors that are not included in the ontology. Although there were some differences in expression of similar factors with respect to those given in the ontology, they did not spell out any extra risks, vulnerabilities, or project characteristics that could lead to cost overrun. These findings demonstrate the completeness of the ontology.

During the interviews, 25 industry practitioners confirmed that the ontological concepts are appropriate to reflect the risk event ,histories of their projects. In total, 75 different international projects performed in 18 different countries were examined and used to question whether the ontology can capture different conditions regarding different projects. Project budgets had a wide range from US$4 million to US$300 million, and durations varied from 12 months to 96 months. The projects were completed with different cost overrun percentages ranging from 0 to 200%. Detailed information about the tested 75 projects is given in Table 4.3. The successful representation of 75 projects with diverse characteristics indicated that the ontology has the ability to capture risk and vulnerability parameters embedded in different kinds of projects for cost overrun estimation. The collected 75 projects will also be used in the development of the case-based reasoning model for cost estimation in further stages of this study. Table 4.4 summarizes the major findings of the validation process.

Table 4.3 Characteristics of the projects identified during interviews

Feature	Category	Number of Projects
Project Type	Building (shopping malls, hospitals, etc.)	13
	Coastal structure (harbor, breakwater etc.)	3
	Dam	7
	Energy (nuclear, hydroelectric plants, etc.)	4
	Housing	3
	Industrial plant (chemical, refinery, factories, etc.)	12
	Infrastructure	9
	Pipeline (petroleum, natural gas)	3
	Transportation	14
	Other	7
Contract Type	FIDIC	37
	Local contract	38
Project Delivery System	Turnkey	45
	Traditional(Design Bid Build)	21
	Engineering, Procurement, Construction (EPC)	3
	Build Operate Transfer (BOT)	6
Payment Type	Cost plus fee	5
	Lump sum	34
	Unit price	32
	Combination of lump-sum and unit price	4
Company Role in the Project	Member of a consortium	12
	Member of a joint venture	14
	Sole contractor	40
	Subcontractor	9
Country	Asia	35
	Africa	19
	Europe	21
Project Size	Smaller than 100 million USD	43
	Greater than 100 million USD	32
Actual Cost Overrun	Smaller than 50%	60
	Between 50 to 100%	11
	Greater than 100%	4

Table 4.4 Outputs of validation process

Metric	Formulation	Value
Number of parameters/attributes identified by experts that are not within the ontology	number	0
Average subjective rating of experts about "completeness of the model"	$\text{Rating} = \frac{\sum(\text{Expert Rating}}{\text{Number of experts}}$	4.7
Average absolute error in cost overrun estimates (with and without ontology)	$\text{Error} = \frac{\sum \lvert \text{actual cost overrun\%} - \text{estimated cost overrun\%} \rvert}{\text{Number of experts}}$	20 % (without ontology) 14 % (with ontology)
Average subjective rating about level of confidence in cost overrun estimates (with and without ontology)	$\text{Rating} = \frac{\sum(\text{Expert Rating})}{\text{Number of experts}}$	2.7 (without ontology) 3.7 (with ontology)
Average number of critical factors (CI) considered during cost overrun estimation (with and without ontology)	$\text{Average} = \frac{\sum(\text{CI})}{\text{Number of experts}}$	10 (without ontology) 16 (with ontology)
The range of project size that can be represented	USD	4 -300 million
Number of countries that can be represented	number	18
Number of different project types that can be represented	number	> 9
Number of different contract type that can be represented	number	2
Number of different project delivery system type that can be represented	number	4
Number of different payment type that can be represented	number	4
Number of different company roles that can be represented	number	4

Although the validity of the ontology was confirmed with respect to the metrics of effectiveness, completeness, and generality, the following issues were revealed during the validation process:

- There were no experts/practitioners who totally disagreed with the ontological concepts, relations, or attributes, and there were no additional items suggested for inclusion in the ontology. However, it was observed that some experts used different expressions for the concepts included in the ontology. Some experts preferred to use a more specific, more general, or different representations compared with the ontology.

- A small number of experts evaluated some concepts as irrelevant to the domain. Experts who had limited experience regarding particular project types and who were unfamiliar with some risk and vulnerability factors mentioned that some concepts could be eliminated. However, as the majority of the experts considered them relevant and provided real evidence from their own projects, it is believed that they should not be eliminated. Historical finding supports such instances. Finally, the evaluation process that aimed to validate the content of the ontology from the viewpoint of the experts showed that the ontology can capture all significant issues related to risk, vulnerability, and cost overrun. It improves the cost overrun estimation process and the confidence level of the estimator.

In spite of different preferences of the experts on particular items existing in the ontology, there was no case that the ontology was insufficient to represent. The majority of the experts confirmed the completeness and effectiveness of the system. As a result, the ontology can be accepted to be fairly effective in relating necessary risk and vulnerability factors with cost overrun, and it can be used for both risk path analysis and cost overrun estimation for international construction projects. The fact that validation results reflect the perception of Turkish contractors only may be a shortcoming that limits the generality of the ontology. However, it is believed that although magnitude of risk and vulnerability may be perceived differently depending on the risk attitude of a decision-maker, which may also be related to his or her nationality, the attributes of risk and vulnerability are similar for all countries, and the ontology can be accepted as general enough to relate the attributes of risk and vulnerability with cost overrun regardless of risk attitude and perception. It is also worth mentioning that the projects mentioned during the interviews reflect mainly the emerging markets served by the Turkish contractors. Although it is believed that the range of countries considered during the validation phase is representative of the global construction activity, it would be better if the generality of the ontology could be tested by considering a higher number of countries, including the developed countries served by international contractors.

Consequently, risk and vulnerability ontology is designed to be used to relate risk paths with cost overrun and simulate risk sharing process between project participants in further stages of the study. The ontology is to collect risk-related project data, develop statistical models to understand reasons for cost overrun, and facilitate learning from previous projects.

4.2 Risk Impact Estimation Stage

As discussed in literature review section in detailed, risk management process is defined as a process starting with identification of risk factors, followed by qualitative and/or quantitative assessment of risk impacts, and finally, development of risk mitigation strategies to maintain an optimum risk-return structure between the project participants (Zhi, 1995; Han et al., 2008). In order to eliminate the detected limitations of current risk management systems, developed ontology will be used in more accurate estimation of risk consequences within this study.

Risk identification and risk impact estimation will be done based on the developed ontology. The outcomes of this process will be used as inputs of the risk sharing negotiation process.

The risk ontology is used as the base structure to develop a prediction model and a structural equation model for the estimation of cost overrun value and most influence level of risk items.

Based on the ontological elements and their interrelations, a survey form is designed and used to collect required data to be used in prediction model. Through the survey, general information companies and projects, factors potentially creating risks, importance level of risks and cost increase rate in each project are collected. With the usage of the collected real cases and additional hypothetical cases, a prediction model is developed by Çelenligil (2010) to estimate cost overrun and probable risk paths for a given project. For the prediction model, case base reasoning technique is used.

Case base reasoning is a computational technique used for predicting the results of a situation through the past experience, information and knowledge gained from similar cases (Aamodth and Plaza, 1994). As described by Lee et al. (2005), case base is to check the similarity with old problems and the most similar case is retrieved in order to use the information of the previous case to solve the current case.

The case based reasoning model used for the prediction of the cost overrun value through similarity with previous cases mainly composed from three sub-case base reasoning models and a rule based model (Figure 4.7). Three similarity models and one rule based model is applied within the prediction model. First similarity model is to estimate the adverse changes within a project based on the vulnerabilities existing in the project. Rule based system estimates the impact of vulnerability (2), manageability of changes", on the level of adverse changes. In similarity model 2, the magnitude of risk events are estimated based on the level adverse changes after manageability. The last similarity model, Model 3, is to predict the cost overrun percentage based on the risk events.

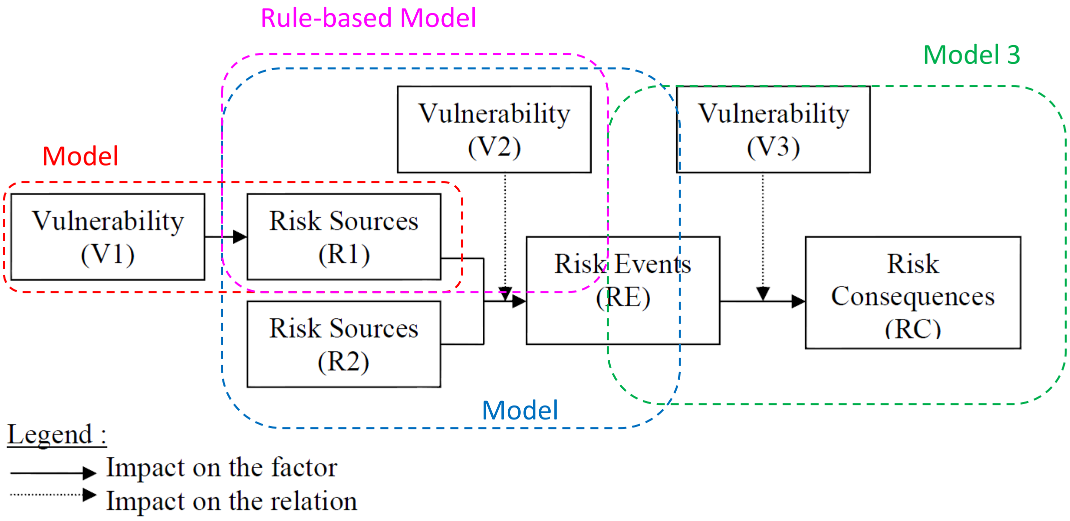

Figure 4.7 Sub models of prediction model

The same projects used for the validation of the risk ontology and formalization of risk event database are used for the development of prediction models. In total 166 past project cases are loaded into the database, 66 of these are real cases and 100 of them are hypothetical. Hypothetical cases are also produced with the help of the same experts taking part in the validation of the ontology, as they are familiar with the terminology and get agree with the structure of the system.

To increase the similarity rating within the collected data set, input vulnerability and output robustness factors are grouped (Table 4.5). Unexpected situations and risk events are kept same as described in previous section.

Table 4.5 Categorization of input and output parameters in prediction model

Input variable (Vulnerabilities)			**First model output variable (Adverse Changes)**	
Item	**Group Heading**		**Item**	**Group Heading**
1	Economic		1	Economic
2	Political		2	Legal
3	Social		3	Politic
4	Legal		4	Partner
5	Market		5	Consultant
6	Design		6	Designer
7	Technology		7	Client
8	Site Conditions		8	Plan
9	External Factors		9	Scope
10	Management Requirements		10	Technology
11	Contract		11	Staff
12	Partner		12	Market
13	Designer		13	Public relations
14	Consultant		14	External factors
15	Client		15	Financial conditions
16	Company experiences		16	Communication between parties
17	Company’s financial conditions		17	Contractor performance
18	Company’s technical conditions		18	Company’s technical conditions
19	Company’s staff			
20	Company’s managerial experience			

To check the case is how similar to the projects in data set, 3 different similarity rule and 5 different evaluation methods are used. In total 15 different prediction systems, based on different similarity rules and evaluation criteria, are checked and 15 different cost overrun values are calculated to figure out the most reliable prediction model (Table 4.6).

Table 4.6 Similarity rules and evaluation criteria used in prediction model

Evaluation Criteria / Similarity Rule	Most similar project values	Average of values of most similar 10 projects	Mod of values of most similar 10 projects	Average of values of most similar 20 projects	Mod of values of most similar 20projects
Parameters have same importance rate	Prediction Model -1	Prediction Model -2	Prediction Model -3	Prediction Model -4	Prediction Model -5
Importance weight of parameters are calculated based on previous projects	Prediction Model -6	Prediction Model -7	Prediction Model -8	Prediction Model -19	Prediction Model -10
Importance weight of parameters are calculated based on expert judgment	Prediction Model -11	Prediction Model -12	Prediction Model -13	Prediction Model -14	Prediction Model -15

These prediction systems are applied for each sub-prediction models and the most reliable system is obtained for each of them.

In order to evaluate the reliability of the prediction model cross validation technique is used. In order to check the reliability of the prediction model cross validation technique is used. In this technique, the data set is divided into smaller sets and the system is tested for each set. The mean and the standard deviations are calculated for each small data set and then the average of them is taken as the error of the whole system.

At the end, the models show that the Project cost increase can be estimated with 7.15% error rate by checking the vulnerability and risk parameters through developed prediction model. More detailed information about the development stages and tests can be found at Çelenligil (2010).

The essential outcomes of the prediction model to be used in this thesis are:

- The cost overrun estimation about the project as the main input of the negotiation process. The project parties will conduct negotiations to share this amount.
- The rate of risk items generating cost overrun. Rates are necessary to figure out the most significant risk items in terms of cost overrun.

While the prediction model figures out the rate of risk items, it does not give information about which risk item plays more crucial role in generation of cost overrun. Therefore, the importance weight of each risk item in generating cost overrun should also be analyzed.

The influence rate of each risk item on cost overrun is checked through structural equation modelling by Eybpoosh (2010). Structural equation modeling (SEM) is a statistical technique used to verify the relations between parameters and the strength of the relations within a model. Within research project, SEM is used to check the parameters and relations between parameters defined in risk ontology and to figure out the influence levels of risk factors on risk consequence based on the same data set used in case base reasoning prediction model development.

As discussed in detail at Eybpoosh (2010), in first step of the structural equation model development, 42 risk-path scenarios are obtained from risk ontology to form the initial construct model and to check if the demonstrated risk paths are meaningful and possible in international construction projects. In the second step, in order to ensure that the risk-path model addresses all possible important scenarios, literature is re-reviewed and experts are re-questioned to define any further critical paths leading to cost overruns other than those introduced in the model. Finally, 46 interactive risk-path scenarios are obtained to construct the SEM model. Several iterative analyses are conducted and necessary modifications are made in the initial model until reaching a model that best fits to the collected data and supports the risk path theory (Figure 4.8). All relationships and path coefficients given in the table are equally significant at the 5% level (Eybpoosh et al., 2011).

Through these statistical analysis; risk paths that are significant in generation of cost overrun are figured out and the impact level of factors on cost overrun are calculated (Eybpoosh, 2010). The calculated impact values of each risk parameter on cost overrun generation are given in Table 4.7. The impact weights of risk factors on cost overrun are the outcome to be used within this thesis, in determination of most critical risk items to be analyzed and discussed.

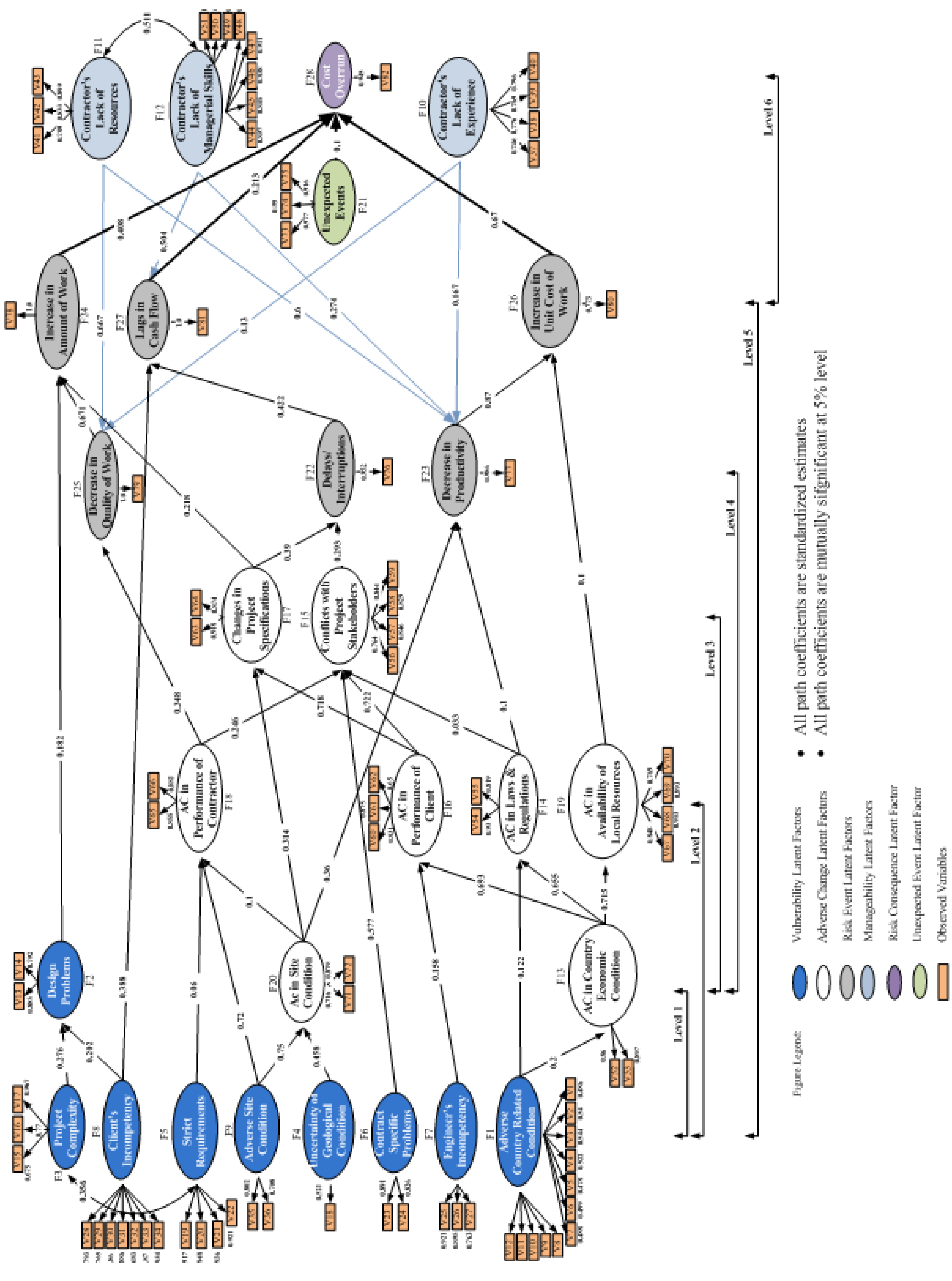

Figure 4.8 Final SEM-Based Risk-Path Model (Eybpoosh et.al, 2011)

Table 4.7 Importance factors of the risk items to be used in the model

Risk Items		Weight		Risk Items		Weight
Adverse change in…	inflation	0.1496		Adverse change in..	attitude of client	0.0220
	tax rates	0.0222			weather conditions	0.0779
	Laws & regulations	0.1048			geological conditions	0.0716
	relations with the partner	0.0549			site conditions	0.0879
	relations with the engineer	0.0199			financial situation of the client	0.0774
	relations with the designer	0.0220			financial situation of contractor	0.0939
	relations with the client	0.0319			financial situation of the partner	0.0260
	Communication btw parties	0.0218			performance of contractor	0.1190
	performance of the partner	0.0220		Unexpected event	War/hostilities	0.0977
	performance of the designer	0.0216			Rebellion/terrorism	0.0950
	performance of the engineer	0.0229			Natural catastrophes	0.0916
	scope	0.4406			Historical findings	0.0915
	design	0.1561			Accidents	0.0914
	technology/method	0.0216			Social unrest/disorder	0.0913
	client's staff	0.0624			Strikes/labor problems	0.0913
	original schedule/sequence	0.0086		Risk event	Decrease in productivity	0.5748
	site organization	0.0228			Increase in quantity of work	0.4800
	project team	0.0793			Decrease in quality of work	0.3220
	top management	0.1017			Increase in unit cost of resources	0.5179
	availability of labor	0.1047			Delay in bureaucracy	0.0900
	availability of material	0.1047			Delay in site hand-over	0.0857
	availability of equipment	0.0568			Delay in logistics	0.0857
	availability of subcontractor	0.0625			Delay in progress payments	0.2030
	public reaction	0.0598				

CHAPTER 5

CONCEPTUAL MODEL: NEGOTIATION PHASE

Risk analysis and risk consequence prediction model are to provide the main inputs of the negotiation system. The estimation of cost overrun amount to be negotiated and the most crucial risks generating budget increase are the starting points of the negotiation. In following stage, the causal risk items need to be investigated in terms of contractual liability and parties will shape their strategies and decide on their limits. Negotiation will be formalized by following the basic negotiation theories and finally parties will come up to a decision, either sharing the cost overrun value or conflict.

Negotiation will be performed in multi agent environment through artificially intelligent agents representing project parties, i.e. contractor and client, to share the risk by eliminating the probable conflicts. Although the algorithm development is an important stage for an automated system, for the full and truly coding the mechanism, defining the context and characteristics of the system components are fundamental.

The basic concepts to be used, the sub-processes of negotiation stage and rules of the system will be detailed under this chapter of the thesis. The automated model and agents in system will be discussed with its all aspects in next chapter.

5.1 Elements of Negotiation in Construction Industry

Developed negotiation model should be specific enough to be helpful and it should be comprehensive and flexible enough to cover various aspects of the process. To achieve such a system, the main concepts need to be understood and taken into account during system development, while minor notions are neglected.

To capture what is the aim, what will be happen through negotiation, how to prepare and how to handle the process; the seven elements, discussed under Research Background Chapter, will provide a powerful approach. The characteristics of the negotiation process in construction industry are investigated through seven interconnected elements of negotiation, i.e. interests, alternatives, relationships, options, legitimacy, communication, commitment.

Interest: The needs, concerns and goals of motivating parties in construction negotiation are mostly linked with the compensation of their monetary losses generated due to adverse changes in conditions or unexpected events. Therefore, the issue to be negotiated in this study will be cost overrun, as being one of the major risk consequence, and the target of each party in construction negotiations will be to maximize its own gain.

Option: The parties will share their monetary based offers with each other to figure out the most acceptable option. The risk sharing negotiation is a competitive negotiation (i.e. one parties gain will be others loss) and instead of focusing on a single option, a range should be defined to increase the options and possibility of acceptance. For the model, the parties will define their ranges between target (highest claimed amount) and reservation (least acceptable amount) values based on their preferences, strategies and legitimacy of parties. Financial strength, claim ability, experience, knowledge and supporting the claim are the critical factors shaping the negotiation power of a party, and hence the range of options.

Relationship: In construction, negotiations take place in the context of an ongoing relationship during project period. As negotiators are contractually connected with each other to complete the project, they should be willing to reach a settlement point and their relations should be constructive. Besides, Contractor usually wants keep the relations in harmony, due to existence of ongoing other projects with same client or with an expectation in getting new projects from the same Client in future. Trust to contractor is another critical factor influencing the evaluation of incomings offers, especially for Client.

Alternatives: Alternatives are the steps that each party should take during negotiation to satisfy his own needs. In case of a disagreement in negotiation, parties need to apply for a more complicated and long resolution technique, which is not a desirable result. On the other hand, by accepting an incoming offer parties are undertaking a risk of losing. Therefore, in each step, parties should compare the incoming offer with the worst alternative in order to understand which one is a less risky alternative for them. As the interest in terms of monetary values in construction negotiations, its alternative shall also be in parallel.

Communication: The interaction starts, once the Contractor submitted initial claim offer to Client. Client evaluates the offer and sends a counter offer. Through concessions made in target offers, parties try to meet at a settlement point. Decisions on the offer, counter offers and concession amount are shaped by target and reservation values defined by the parties as well as the risk undertaken by each party by accepting an offer.

Legitimacy: There should be some standards that parties use to legitimize their offers. Fairness is a governing issue in negotiations, which is shaped through contract in construction projects. Therefore, in construction industry contract forms the basis of legitimacy. Factual and legal supportive documents about risk items generating cost overrun are important factors in getting more in the negotiation. In construction, as contractor is obliged to submit the claim case with all details, in model all information related with the case and conditions of the each party are accepted to be known by both parties.

Commitment: As parties are contractually bounded and the target is to complete the project successfully for both construction parties, commitment inherently exists in construction negotiations. Commitments given on your own or together with the opponent, like time frame and steps to implement, may reduce your own and the other party's range of options, however will help parties to reach a settlement more easily. Contractor and Client are usually willingness to close negotiation at earliest to minimize overhead costs and to maximize investment revenue cost. Therefore, time is a critical factor influencing commitment.

5.2 Negotiation Process Phases

Negotiation activities can be divided into three basic phases. The first phase is the preparation stage where the necessary information is gathered to figure out the options and solutions. Parties identify their needs and evaluate counter party, gather information about the situation. Second stage is the main interaction stage where information is exchanged and bargaining take place. The objective of this mid-phase is to reach an agreement. Closure is the final stage that the outcome of bargaining is decided and commitment is given.

The sub-processes to be followed in negotiation stage are summarized in Table 5.1.

These three phases are recommended to be included in a successful electronic negotiation platform (Merz, 1998; Calosso et al. 2003), and will be considered in development of the model described in this thesis.

Table 5.1 Main negotiation phases

Negotiation Stage	Sub-stages in Risk sharing Model
Preparation Stage	1. Situation assessment 2. Attribute evaluation
Bargaining Stage	3. Utility determination 4. Making first offer 5. Evaluation of risks taken by agents to decide which agent should make a concession 6. Determining concession amount 7. Making counteroffer/offer
Closing Stage	8. Making decision to accept or conflict

The individual components and stages within the model are demonstrated by unified modeling language (UML) class diagrams, as it helps to standardize a complex system model and provides basis for software implementations (Calosso et al., 2003). Class diagram is developed in order to collect the static model elements, their content and relations. Class diagrams are mostly used for the analysis and design of the conceptual model of a domain and accepted as the initial stage of a system design (Bauer and Odell, 2005). The class diagram and data types developed will form the basis for the software.

5.2.1 Preparation Stage

First step in negotiation is the preparation stage which includes the investigation of case, information gathering, determining your options and defining your BATNA. This stage has a vital importance as the negotiating parties determine their negotiation positions at this stage.

As being one of the most cited references in literature, Thompson (1998) recommends in his book “The mind and the heart of the negotiator” that there are three main stages of negotiation preparation: situation assessment and attribute evaluation (i.e. self-assessment and sizing up other party).

5.2.1.1 Situation assessment

In the developed system, situation assessment involves the evaluation of project vulnerabilities, adverse changes in project conditions and their consequences. Through analysis of the situation, firstly the necessity of a negotiation is questioned, i.e. whether there is a cost overrun in project or not. If it is found out that there is cost overrun larger than zero; then its value, its reasons and the responsibility distribution among project parties need to be determined. Risk originated cost overrun value determination and analyze of its reasons are performed through prediction system, while responsibility of parties on these risks are investigated through contract conditions.

As described in previous sections, the prediction system is to estimate the possible cost overrun ratio based on the vulnerability level of the projects defined by the Contractor. Through case base reasoning (CBR) analysis, the cost overrun ratio is determined on a 0% to 100% scale and the magnitude of each risk item is estimated on 1-5 scale. To determine the most important risk items generating cost overrun, the magnitude of risk items determined by CBR is multiplied by impact degree of risk items on cost overrun determined by structural equation modeling (SEM).

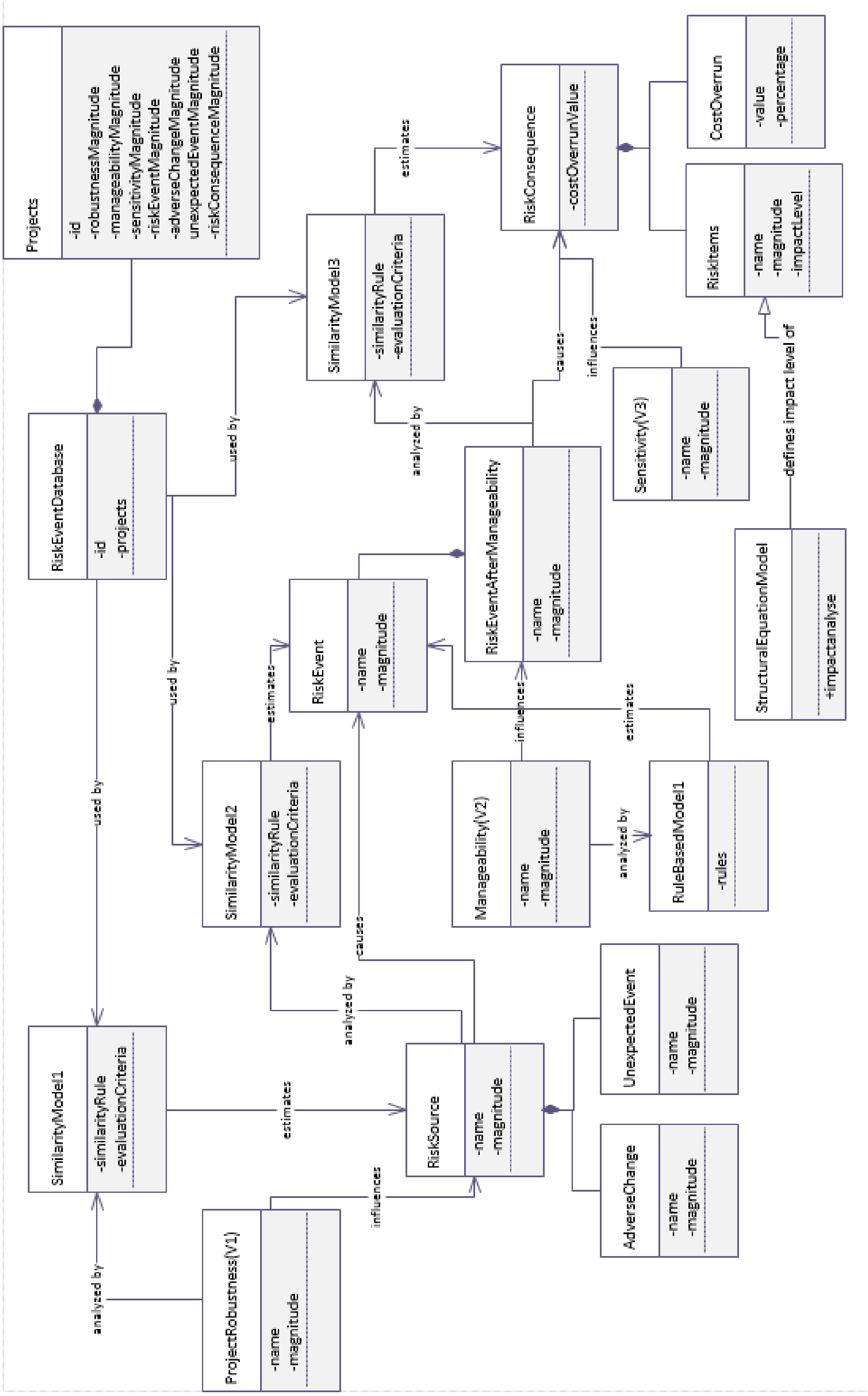

Figure 5.1 Class diagram for Risk Analyze Process

With multiplication of each risk item magnitude and impact degree, most triggering risk items will be figured out and their individual contribution to cost overrun will be analyzed. The risk items having larger portion in cost overrun generation will be checked under contract conditions to figure out the responsible parties. The risk analyze process is summarized in class diagram given at Figure 5.1. The risk related items (risk sources and risk events) defined in ontology are checked through FIDIC type contract. The static structure of the contractual liability determination process is represented in class diagram given in Figure 5.2.

While the contract is a project specific document and it is not easy to exactly define which party is responsible, a basic division is made based on contractor, client or shared responsibilities for the risk related parameters used in the model (Table 5.2). By considering the possibility of having different responsibility distribution in different type of Contracts and having some risk items that is not covered by contract, automated system need to be developed flexible enough to make necessary changes in the responsibility assignment and reflect users' own contract conditions.

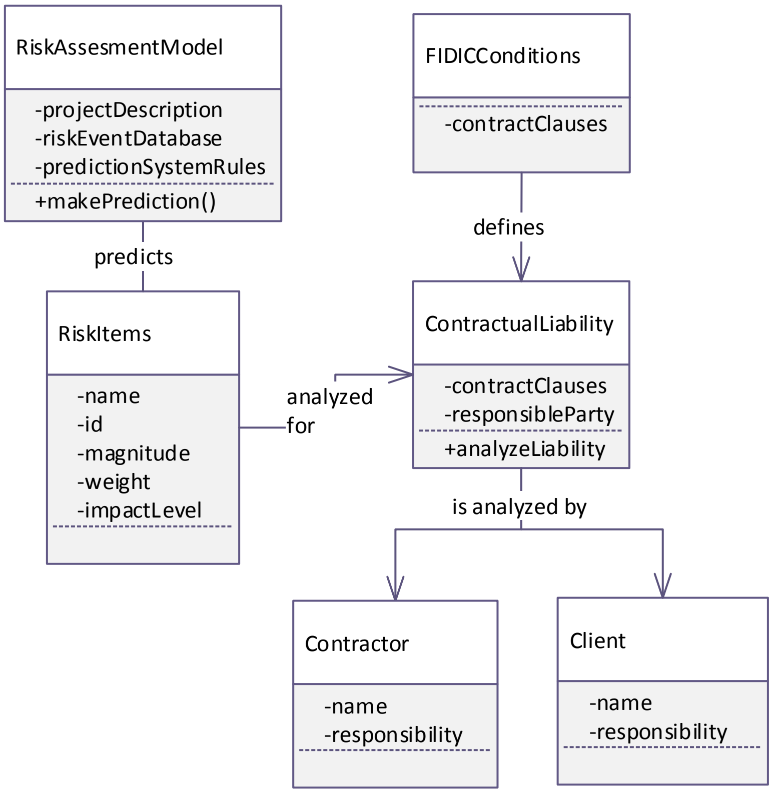

Figure 5.2 Class Diagram for Contractual Liability Analysis

Table 5.2 Risk Sharing in FIDIC Type Contracts

Variables	Risk Sharing
Adverse change in currency rates	Shared Due to Source
Adverse change in inflation	Shared Due to Source
Adverse change in tax rates	Shared Due to Source
Adverse change in laws and regulations	Client
Adverse change in relations with the government	Shared Due to Source
Adverse change in relations with the engineer	Shared Due to Source
Adverse change in relations with the client	Shared Due to Source
Adverse change in attitude of client	Shared Due to Source
Adverse change in public reaction	Contractor
Adverse change in performance of the engineer	Client
Adverse change in client's staff	Shared Due to Source
Adverse change in financial situation of the client	Client
Adverse change in scope	Client
Adverse change in design	Client
Adverse change in technology/method	Contractor
Adverse change in site organization	Contractor
Adverse change in project team	Contractor
Adverse change in performance of contractor	Contractor
Adverse change in top management	Contractor
Adverse change in financial situation of company	Contractor
Adverse change in availability of labor	Contractor
Adverse change in availability of material	Contractor
Adverse change in availability of equipment	Contractor
Adverse change in availability of subcontractor	Contractor
Adverse change in geological conditions	Contractor
Adverse change in site conditions	Contractor
War/hostilities	Client
Rebellion/terrorism	Client
Natural catastrophes	Client
Historical findings	Client
Social unrest/disorder	Client
Decrease in productivity	Shared Due to Source
Increase in quantity of work	Shared Due to Source
Decrease in quality of work	Shared Due to Source
Increase in unit cost of resources	Client
Delay in progress payments	Client

5.2.1.2 Attribute evaluation (Self-assessment and sizing up other party)

Attribute evaluation is essential to define the utility curves of the negotiating agents, which depends on target and reservation points. Reservation point, also named as BATNA, is a commonly emphasized factor in literature due to its importance in shaping the project outcome. According to literature review and pilot studies conducted in early stages of this project, the most critical stage in negotiation is determination of BATNA. With the purpose to identify the factors shaping BATNA, the findings of the literature review are questioned with the consultancy of 7 experts, each having at least 10 years of experience in construction management domain. Experts are selected by considering their experience level in preparation of construction claim files and their resolution. Two academicians, three project managers, one senior planning engineer and one consultant are interviewed. Instead of following a structured questionnaire, the experiences of the experts on different cases are asked.

The aim of the interview was to decide on the main factors in negotiation and role of the factors in shaping the strategies of parties in negotiation. The list of attributes is decided through interviews with experts and the effect of these attributes on strategy of parties is questioned. Through interviews, the mathematical formulations are also developed to draw the utility curves of the negotiating parties. Mathematical models are the over simplified adaptations of the real life, in which it is assumed that negotiation process is well-structured and results in agreement (Sycara and Dai, 2010). Attribute evaluation will be done by the negotiating parties separately.

5.2.1.2.1 Strategy of Contractor

The common attributes mentioned by experts in formalization of the strategy of the contractor agent are mainly related with the contractual responsibilities and power in negotiation. Outputs of the risk analyze model gives the main inputs for contractual liability checks. Together with power determinants, rated by the user, responsibility distribution forms the basis of the strategy. The interaction of contractor with these factors and risk analyze model are summarized in Figure 5.3.

Parameters related with supporting claim, experience, relations, belief on strength of Client are the power determinants that shape the general strategy of the Contractor and assist him to calculate negotiation power, which is related with probability of gaining in negotiation. Different than power determinants which form the general strategy, contractual liability forms the item-wise approach, as the contractual liability will be different for each risk item. In addition to these factors, time limitation is mentioned by experts to be an important factor in formalization of concession tactic of the contractor during negotiation process.

Determination of target and reservation values is the primary aim in formalization of strategy. Experts mentioned the fact that contractor will try to get the maximum amount from the Client, which is the target value. However, the power of contractor will influence the probability of getting this targeted amount from opponent party. The factors influencing the negotiation power of contractor will have importance level as well as a rating varying for each contractor. The common factors, mentioned in literature and by experts, with their normalized average influence weights, decided by experts, are demonstrated in Table 5.3.

The claimed money depends basically on the contract clauses. A loss can be claimed only if that party is contractually not responsible from that risk. Therefore, the sum of cost overrun generated from risks that are contractually defined as “client” or “shared” responsibility will be the target claim amount of Contractor (Equation 1).

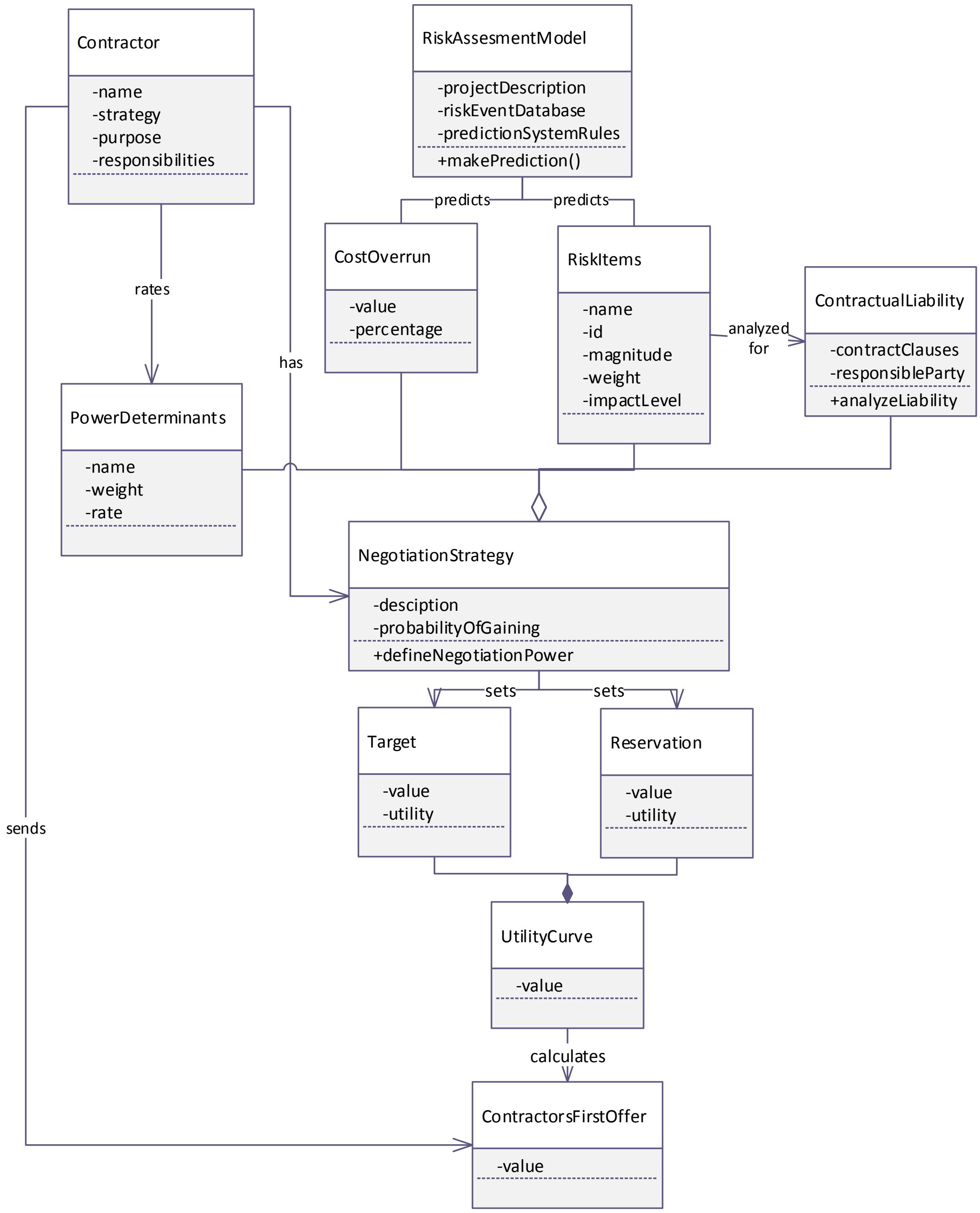

Figure 5.3 Class Diagram of Contractor's Preparation Stage

Table 5.3 Factors influencing contractor's negotiation power

Factor	Description	Influence weight
Commitment of internal resources	Sufficiency of financial, technical and managerial sources and skills to handle the negotiation process	0.14
Experience in claim management	Capability of staff in preparing litigation and make negotiation with Client	0.15
Knowledge of contractual liabilities	Sufficiency of knowledge to correctly interpret the contractual clauses and liabilities	0.16
Strength of supportive documents & facts	Appropriate record and presentation of all evidences	0.20
Existence of other projects with same Client	Existence of current projects with the Client and the ratio of projects with same client to all projects of contractor	0.06
Impacts on future business relationships	Work continuity and probability of having new projects with the client	0.09
Bureaucratic ease to negotiate with Client	Easiness to make negotiation with client before applying to other dispute resolution methods	0.1
Low knowledge of Client	Perception on level of Clients knowledge and experience to analyze the existing risks events, their sources and impacts	0.12
	Total	**1.00**

$$\textit{Contractor's Target} = (\textit{Cost overrun})_{Client} + (\textit{Cost overrun})_{Shared}$$

(Equation 1)

The factor listed in Table 5.3 will be used for evaluation of reservation point. Position determinants will be rated by the program user as per to project and company characteristics. Multiplication of importance weights with rates will reveal the degree of power (Equation 2).

$$\textit{Contractor's negotiation power rate} = \sum (\textit{importance weight}) \times (\textit{rate of parameters}) \qquad (\textit{Equation 2})$$

The minimum value to be accepted in negotiation, i.e. reservation value for Contractor, will be the risks under responsibility of client with the multiplication of gaining probability (Equation 3).

$$\textit{Contractor's Reservation} = (\textit{Cost overrun})_{Client} \times (\textit{Negotiation Power Rate})_{Contractor} \qquad (\textit{Equation 3})$$

After calculating the target and reservation values, Contractor settles the utility curve and sends the initial offer to the Client to start the bargaining process.

5.2.1.2.2 Strategy of Client

Interviews performed with experts for Contractor strategy, is repeated to understand how the Client position is shaped. The common factors mentioned experts are related with experience, knowledge and trust. The list of commonly mentioned factors and average normalized importance weights are demonstrated at Table 5.4.

Table 5.4 Factors influencing client's negotiation power

Factor	Description	Influence Weight
Commitment of internal resources	Sufficiency of financial, technical and managerial sources and skills to handle the negotiation process	0.23
Experience in claim management	Capability of client staff in analyzing the incoming claim and make negotiation with Contractor	0.27
Knowledge of contractual liabilities	Sufficiency of knowledge to correctly interpret the contractual clauses and liabilities	0.18
Knowledge and control on Project	Sufficiency on knowledge and experience to analyze the existing risks events, their sources and impacts	0.23
Mistrust to Contractor	Low confidence to contractor	0.10
	Total	**1.00**

These factors are related with the negotiation power of Client, in other words, it is related with the winning probability of Client in bargaining. Power determinants will be rated by the program user as per to project and client characteristics and multiplied with importance weights to calculate the probability (Equation 4).

$$\textit{Client's negotiation power} = \sum (\textit{importance weight}) \times (\textit{rate of parameters}) \qquad \textit{(Equation 4)}$$

Target of Client will be to pay the minimum amount, which equals to the cost overrun value generated due to risks contractually under his responsibility. However, in parallel to his power in negotiation, this value will also be adjusted (Equation 5).

$$\textit{Client's Target} = (\textit{Cost overrun})_{\textit{Client}} \times (1\textit{-Negotiation Power Rate})_{\textit{Client}}$$

(Equation 5)

Reservation value of the Client is the maximum amount he can give in return to the incoming offer (Equation 6).

$$\textit{Client's Reservation} = (\textit{Target})_{\textit{Contractor}} \times (1\textit{-Negotiation Power Rate})_{\textit{Client}}$$

(Equation 6)

The concepts related with the client and his strategy is summarized in Figure 5.4.

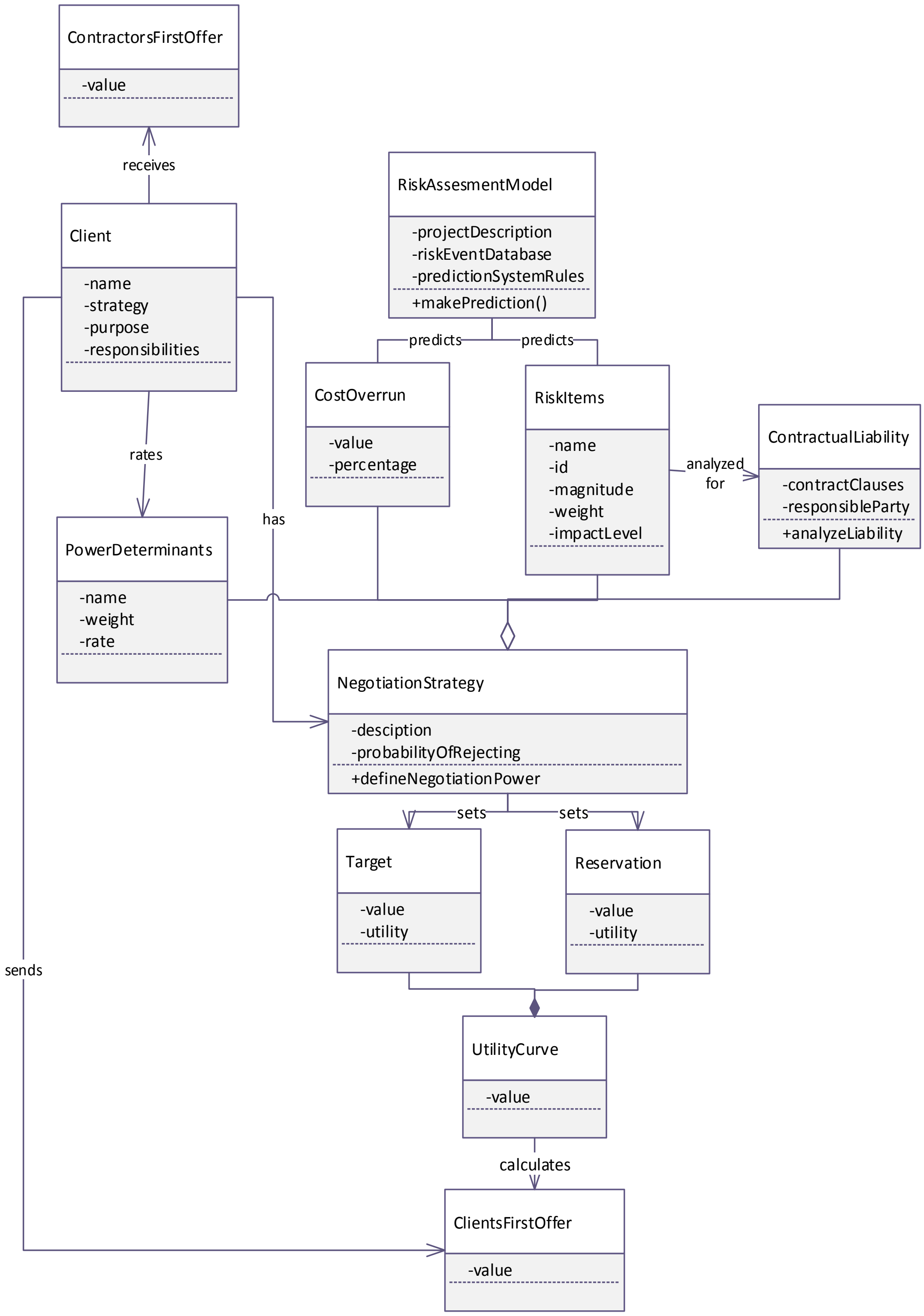

Figure 5.4 Class Diagram of Client's Preparation Stage

5.2.2 Bargaining Stage

Once the negotiation zones are settled, bargaining process starts to share the pie. Sub-stages of bargaining stage are utility determination, making first offer, concession making when necessary and re-sending a counter offer.

During bargaining stage, while utility determination and first offer are done only once, evaluating the incoming offer and making counter offer is a loop cycle continues until a settlement is reached.

5.2.2.1 Utility Determination

After the attributes of the parties are described, the utilities should be defined to mathematically formalize the negotiation. In the target point, utility is accepted as the highest value (i.e. utiliy=1) and reservation utility is usually defined by the negotiators (i.e utility is between 0-1) (Figure 5.5). In this thesis, utility at reservation is accepted as 0.6. At conflict case the utility is accepted to be zero.

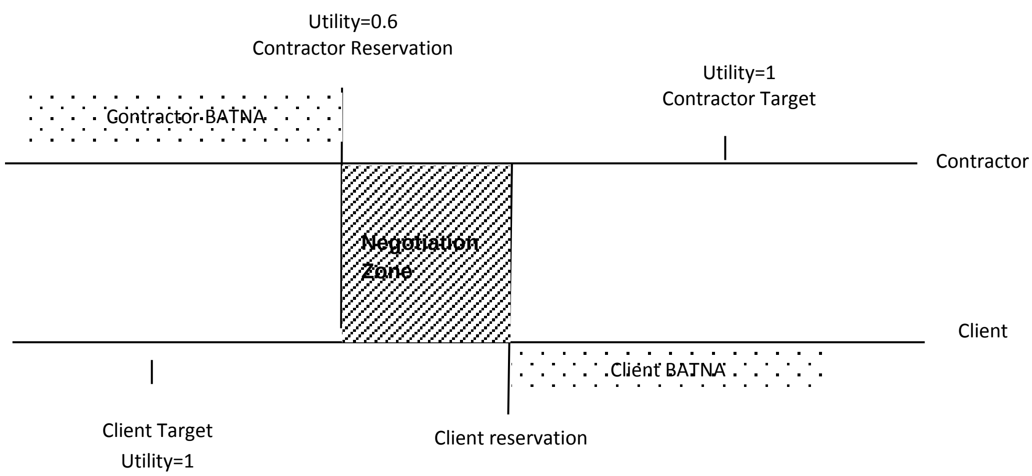

Figure 5.5 Utility in Negotiation

Utility curve of the agents will be drawn between defined negotiation points. i.e a straight line passing through points [target value, utility at target] and [reservation value, utility at reservation].

Utility curves are important in the analysis of the agents during negotiation. Through utilities, agents will calculate their willingness to take risk of conflict at each stage and the party taking less risk should make concession to continue negotiation.

5.2.2.2 Making first offer

After presenting the space of possible deals, the rules of the acts within this zone are defined. Similar to most of the business deals, in construction industry the first offer is given by the Contractor as the Client considers himself in a position of power in concluding the case.

The first offer will be sent by the contractor and the value of the offer equals to the contractor's target value. The opening offer helps to orient the Client's perception on the negotiated issue. Too aggressive or too low offers made in initial stage will cause the contractor to lose, as reaching a settlement or gaining what is needed will become difficult in both cases.

The initial counter offer will be done by the client and the value of this offer is accepted to be equal to the target value of the client.

5.2.2.3 Making Concession

Bargaining is considered as a process of give and take. In order to reach a settlement, parties should be willing to make concessions. As discussed at research background section, the negotiation protocol applied in the model is monotonic concession protocol, in which each party makes concessions starting from target value and tries to reach settlement point through concessions. Settlement point remains between the reservation points of the negotiators.

To decide which party should make the concession the risk evaluation strategy defined by Zeuthen Strategy is used. According to this strategy at each negotiation step, parties evaluates their willingness to take conflict risk, which is calculated by dividing (the loss due to accepting opponents offer) to (the loss due to going into conflict) as shown in Figure 5.6.

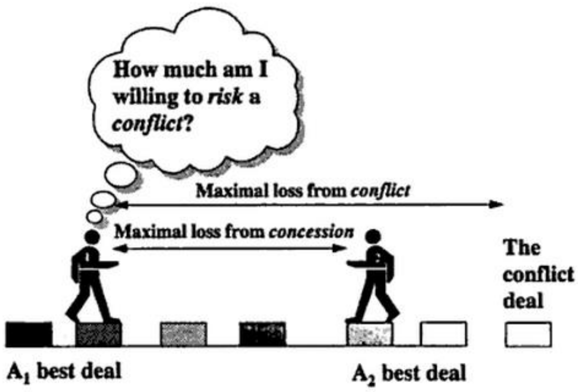

Figure 5.6 Risk Factor (Rosenschein and Zlotkin, 1994)

The party with minimum willingness to take risk of conflict makes the next concession. The amount of concession is the minimum sufficient value that makes the agent's risk level same with the opponent. The risk formula will be applied is given in Equation 7.

$$Risk = (Uaa - Uao) / (Uaa - Uc)$$

(Equation 7)

Risk= willingness to take conflict risk
Uaa= Utility of agent with his offer (this is 1 at target value)
Uao= Utility of agent with opponent offer
Uc= Utility of agent at conflict (here conflict utility is accepted as zero)

One important issue to solve negotiation problem will be the time limitation factor. As negotiation rounds increases each party loses extra money. Time limitation factor will be reflected to negotiation process is given in Equation 8.

$$\text{Real value of Offer} = (\text{Offer Value}) / (1 + t)^N$$

(Equation 8)

Real value of offer= the next offer to be sent to opponent
Offer value: calculated value by Zeuthen formula
t: time limitation factor (between 0-1)
N: number of negotiation rounds

5.3 Combined Conceptual Model

The developed class diagrams clearly demonstrates that the model defined in Chapter 4 provides the initial information needed for Client and Contractor's analysis to start negotiation. The risk data on cost overrun value and triggering risk items forms the basis of the parties strategies, and hence to shape their utility curves. Figure 5.7 shows the main flow between conceptual models defined under Chapter 5 and Chapter 5 of the thesis. Multi agent system to be developed will be designed based on this structure.

The class diagram demonstrating the main classes in Zeuthen strategy is given in Figure 5.8

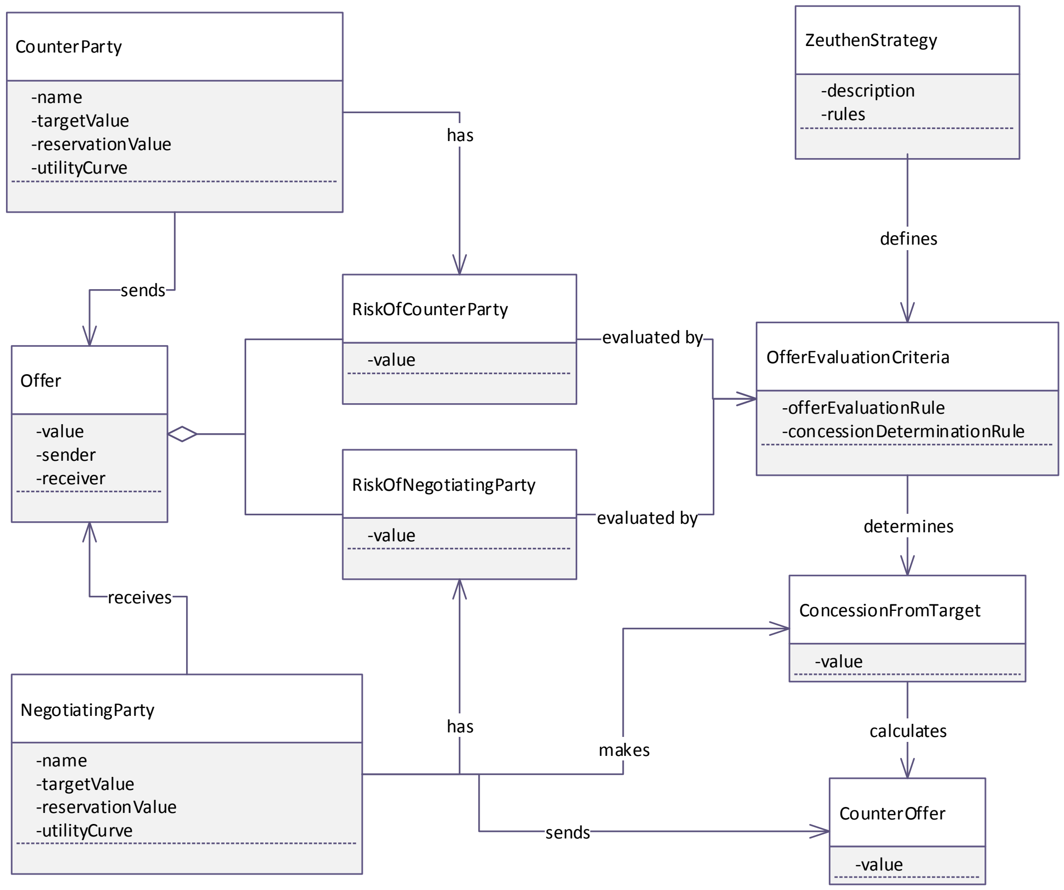

Figure 5.7 Class diagram for Zeuthen Strategy

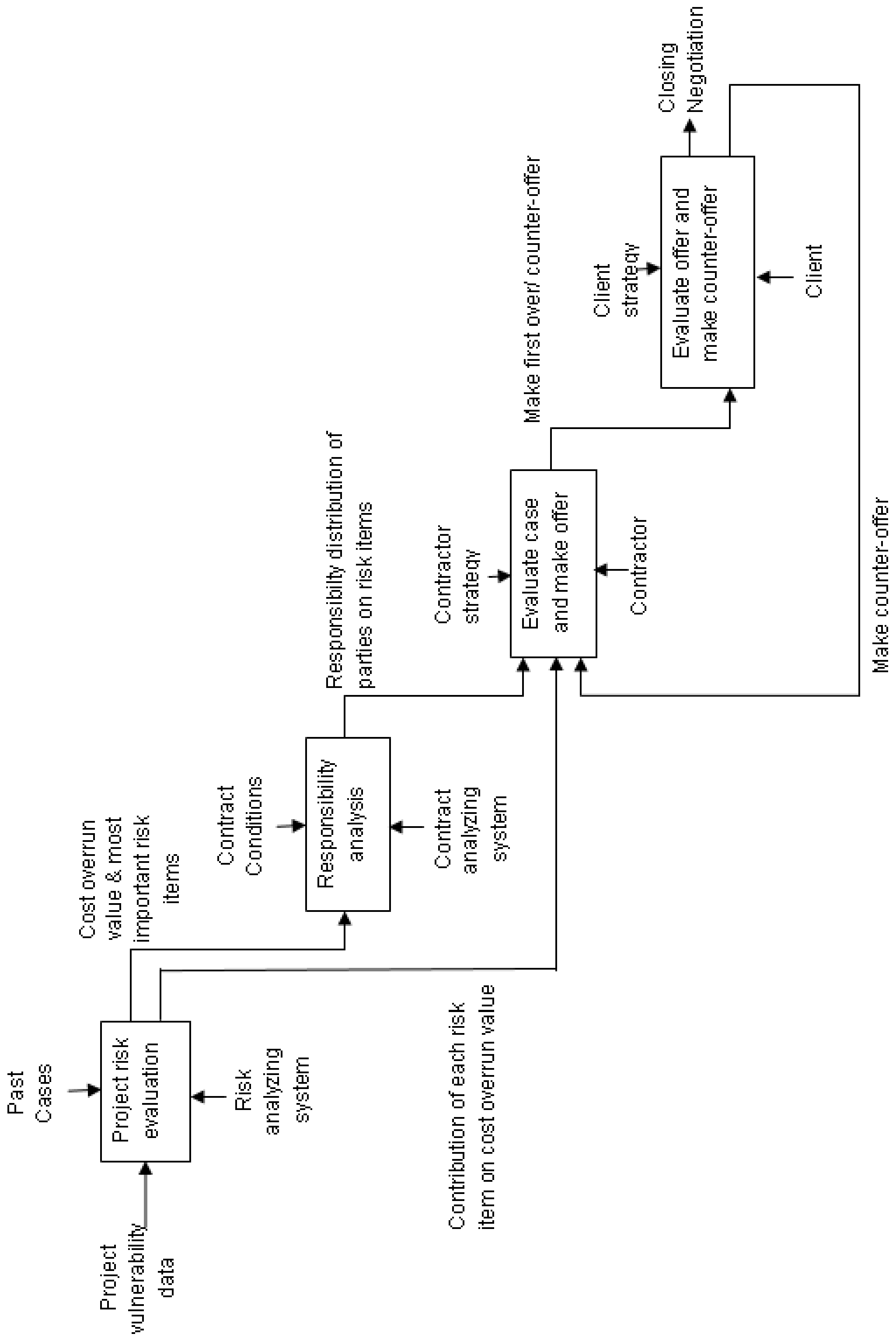

Figure 5.8 Combined structure of conceptual models given in Chapter 4 & 5

CHAPTER 6

MULTI AGENT RISK SHARING PLATFORM

In conceptual model development chapters of the thesis, the general structure, main features of system, the information to be loaded and wanted from the system, the sub-structures and the information flow between these structures are defined in detail. Development of a multi agent risk sharing platform discussed under this chapter is related with the implementation of conceptual models with artificial intelligence technology through the agents in multi agent environment.

In the multi agent platform, the stages of conceptual models, i.e. defining risks, analyzing their consequences, checking contractual liability, defining strategies and preferences of negotiating parties and performing bargaining process will be conducted by intelligent agents to solve the conflicted risk issues. In this chapter, concepts related with the implementation of system, key agents, their behaviors and interaction will be discussed.

6.1 Toolkits to be used in System Development

There are several agent toolkits developed for setting agent infrastructure and applications. ZEUS developed by BTexact at 1997, RETSINA developed by Carnegie Mellon University Robotic Institute in 1995, IMPACT developed through a research project undertaken by several universities in different countries and JADE developed by TILab at 1999 are some of the mostly used agent development toolkits.

While all of the systems have their own benefits, Java is selected as the programming language for the development of the software model and Java Agent Development Framework (JADE) is selected as the system framework, as recommended by Karakaş et al. (2013).

JADE is one of the mostly used agent oriented middle-ware that uses Java language and makes the agent implementation easier by supporting debugging and deployment phases (Nikraz et al., 2006). JADE provides graphical tools to simplify the multi-agent systems development and uses FIPA (Foundation for Intelligent Physical Agents) specifications, which is the main standard provided by IEEE (Institute of Electrical and Electronics Engineers) Computer Society for agent-based technologies.

As defined in detail under the User’s Guide of JADE (2009), agents are created under classes with a unique name and they perform their responsibilities through defined behaviour classes (i.e. role protocols). The behaviours of an agent describe its ability to reach and solve problems whether communicating with other agents or acting on its own (Marik et al., 2003). Behaviour will be one shot (run only one time), cyclic (run until agent terminates) or generic (control the agent terminations). Defining the behaviours of an agent is the most crucial part of the agent implementation stage.

Agents are communicating with each other through the exchanged messages. Once a message is received, agent interprets its content and performs his own analysis based on its defined behaviors. FIPA specifications provide 22 communicative acts (including accept or a request, agree, call for proposal and propose an answer, confirm, inform, request, etc.) that an agent can use while performing its analysis and interpretations. For agent communication, each message exchanges between agents is defined by sender, a receiver, a content, a language, encoding, protocol, id, in reply to and reply by features in the system.

Agents accept the incoming messages by using “receive” act. Since an agent behavior, responsible from receiving the messages, does not know when a new message will be received and when it will become activated, receive behavior is defined as a cyclic behavior that will check the message queue continuously. If the received message is empty, the behavior will be blocked.

To indicate the acts of the agents throughout the process, UML (Unified Modeling Language) state diagrams and UML sequence diagram are used within this thesis for agent behavior and agent interaction representation respectively.

A state shows what an agent is doing, i.e. performing an analysis, computing and sending a message in action state or waiting for a message in wait state (Marik et al., 2003). The different states composing the behavior plans describe the sequence of actions, an agent has to perform in a particular context, and they are used as a guide for the implementation of agent.

States are described by three possible behavioral patterns:

- entry - triggers automatically when entering a state.
- exit - triggers automatically when exiting a state.
- do - is triggered over and over as long as the state isn't changed.

A sequence diagram focuses mainly on the message interchange between a number of entities used in software development processes (Bauer and Odell, 2005).

6.2 Multi Agent System Development

Multi agent systems are to model problems that have multiple solutions within a range formalized through inputs of several entities and do not depend on simple rules. The choice of multi agent technology for the representation of risk sharing model is motivated by the fact that analysing and sharing risk within a project necessitate the joint workout and collaboration of different entities.

As defined in conceptual model development chapters, there are four fundamental characters in risk sharing process of an international construction projects: risk analyzer, contract, contractor and client. Each of these characters is represented by an individual agent within the multi agent system.

6.2.1 Risk Analyzer Agent

Risk analyzer agent is responsible from the analysis of risk and vulnerability parameters to figure out their effect on the project budget through the CBR model described in conceptual model in Chapter 3. Risk analyser agent initially figures out whether there is a budget change and there is a need of negotiation. It performs the prediction of cost overrun value and magnitude of individual risk items contributing to this cost increase. Analyser agent takes information from the system user and submits the risk and cost related data to the Contract Agent.

Figure 6.1 show the state diagram of the risk analyser agent to describe its behaviors through this process. As described in conceptual model of negotiation system, there are two main analyse results: cost overrun value generated from risks and magnitude of risk items generating cost overrun. These outputs are used as the main inputs of the all other mechanism, i.e. analysing contract, contractor and client conditions. When the logic in construction claim management process is considered, the risk items and cost overrun related information should be transferred to Client through the Contractor within a claim file. Therefore, output results will be shared only with contract and contractor agents within the model and transferred to other agents across these agents.

After the agent is created, it opens the GUI and waits for the user inputs. To continue its operation, the user should fill the information requested by GUI and should start comparison. Afterwards, the risk analyser agent sets the indexes from GUI, uploads the risk event database to be used in similarity check, performs the analysis, prints the results and starts waiting for a request message from other agents.

The initial interface is the data input stage related with the project. Figure 6.2 shows the Data input GUI (Graphical User Interface) of Risk Analyser Agent.

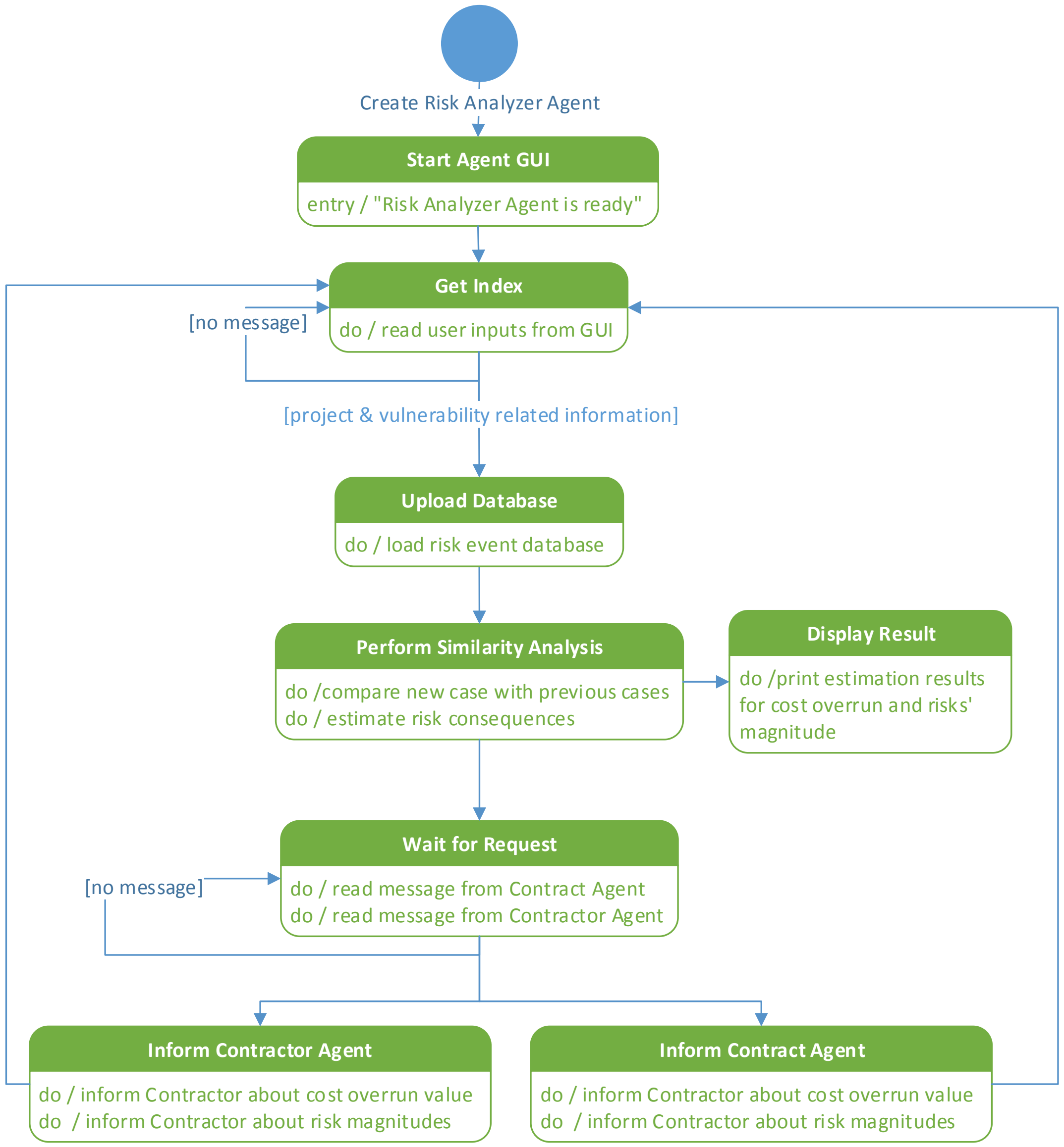

Figure 6.1 State diagram of Risk Analyzer Agent's Behavior

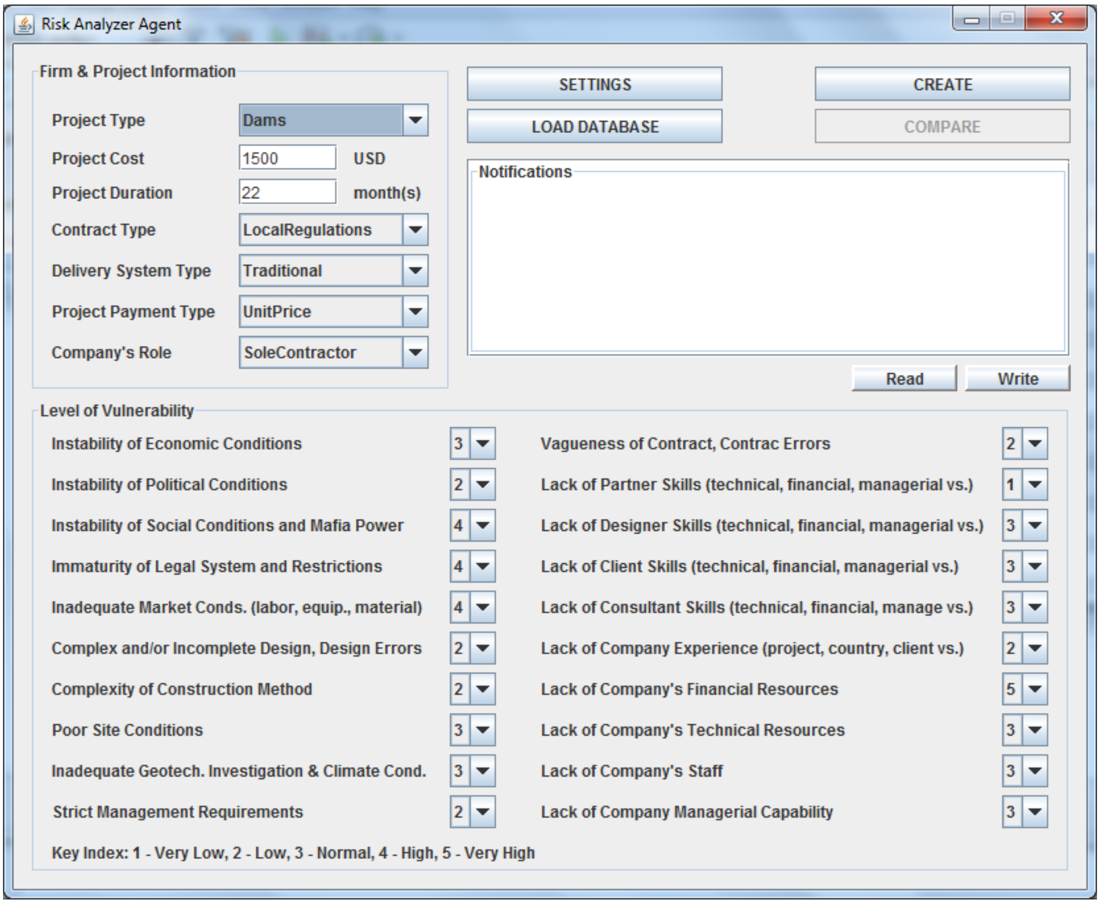

Figure 6.2 Data Input GUI for Risk Analyzer Agent

The GUI has 3 main parts:

- Project & vulnerability related information input section. The user gives basic project and company related information either entering by hand or choosing from a dropdown list. The level of vulnerabilities in the project on is defined by a 1-5 scale.

- Selection of CBR settings and risk event database by the user. The risk event database used within this study is formalized through the data from

161 real and hypothetical projects as described in detail in Chapter 4 of the thesis. The user is also free to use his own database, which need to be developed by following the ontological stages described in previous chapters.

- Saving the case. Read and write options are the shortcuts designed to read a previously defined case and write it again when it is going to be needed. As the software will be used for checking several alternatives and making simulations, the user will need to use the same project data several times and these shortcuts will make user to enter the project data in a shorter time. Read/ write options are also added in some of other GUIs with same purpose.

As discussed in detail at Chapter 4.2: Risk Impact Estimation, there are four main CBR models used for the prediction. The rules used for prediction are listed under "settings" button in the Risk Analyzer Agent GUI User is free to choose similarity criteria and importance factors under this button, if he is going to use another database from the defined one under this thesis.

The main outputs of the model printed as separate interfaces (Figure 6.3 and Figure 6.4). In the output GUI the magnitude of all risk factors and cost overrun value are listed. The top 10 risk items are not demonstrated in the GUI, as they will be shown in contract administrator agent's interfaces.

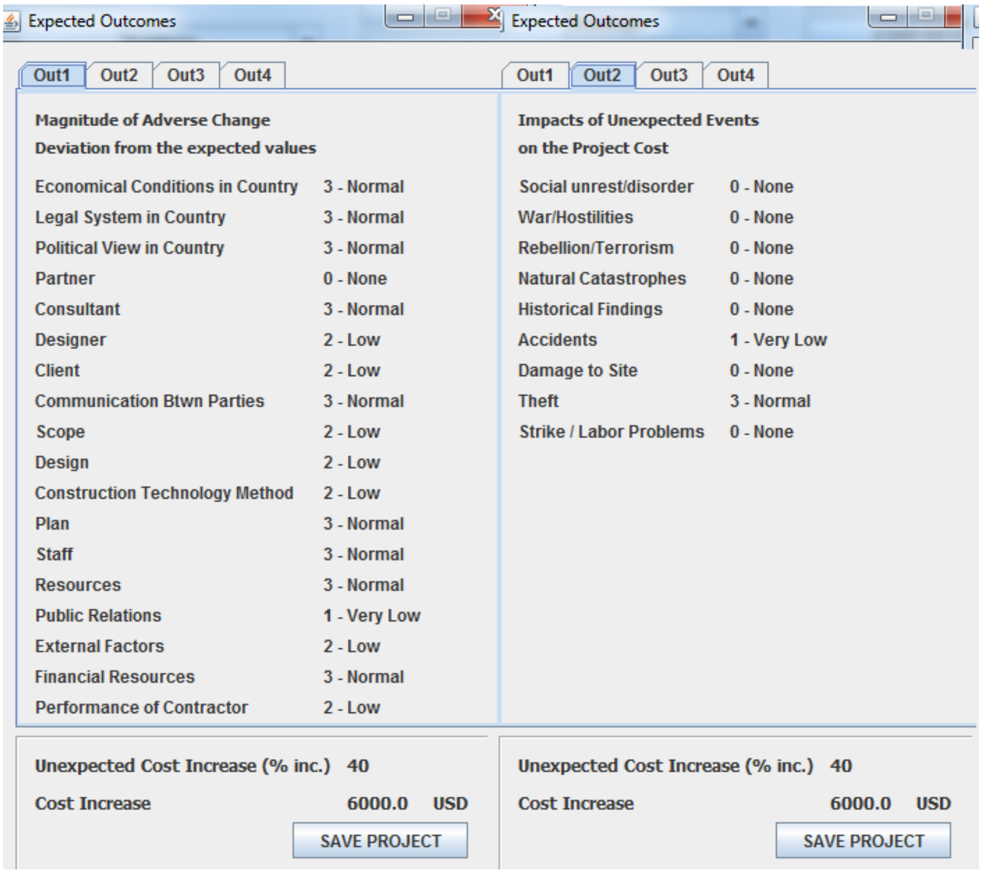

Figure 6.3 Risk Analyzer Agent Output GUI Pages 1&2

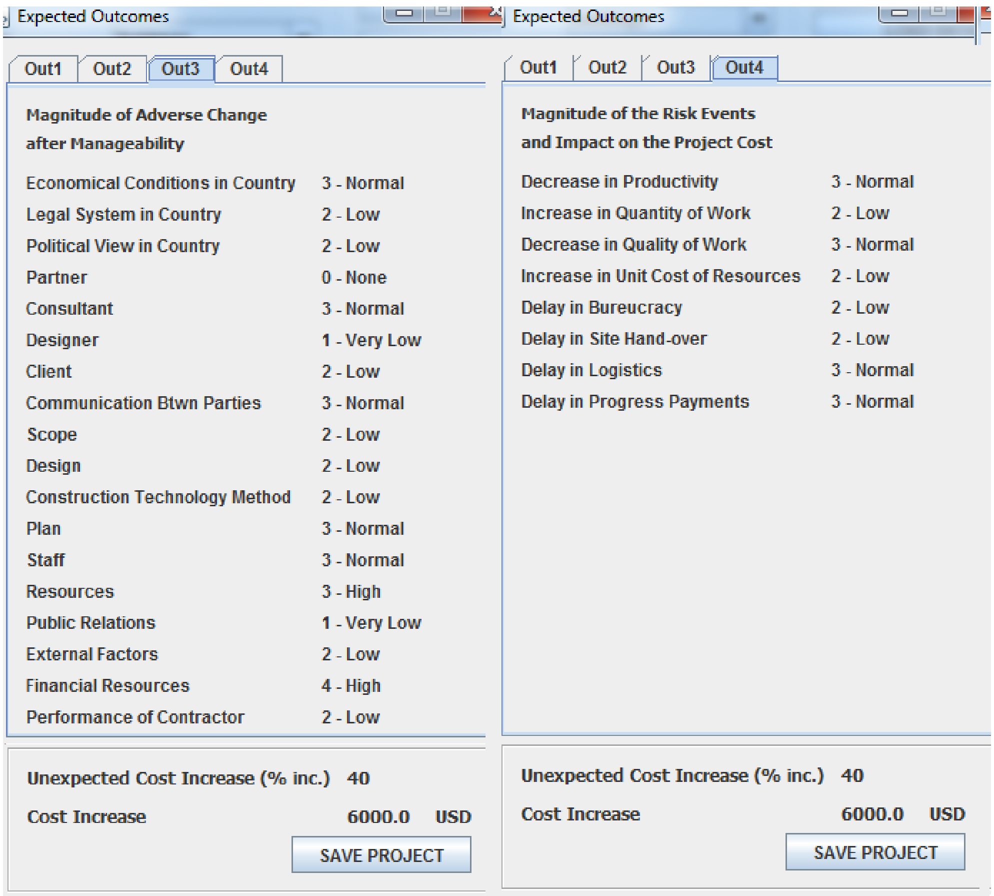

Figure 6.4 Risk Analyzer Agent Output GUI Pages 3 & 4

6.2.2 Contract Agent

Contract agent is responsible from the analyses of the contract conditions and make the initial risk sharing based on the contractual clauses.

Figure 6.5 demonstrates the state diagram of Contract Agent's behaviors. After the agent become activated, it requests risk related analyze results of the Risk Analyzer Agent and checks the responsible party as per to contract conditions for the highly influential risk items. Contract Agent uses the FIDIC conditions and made responsibility distribution as contractor, client or shared responsibility. As the contractual conditions will vary from project to project, the user is let free to make any change in the responsibility assignment. Moreover, the user is also made free to make any change in the list of top risk items.

After determining risk items and the responsible parties from these risks, the agent waits in an idle mode until receiving information request from risk Analyzer Agent Contract Agent shares the analyze results with these agents and again starts waiting in idle mode.

Contract Agent has only one GUI (Figure 6.6) that User can check the top risk items and make necessary modifications.

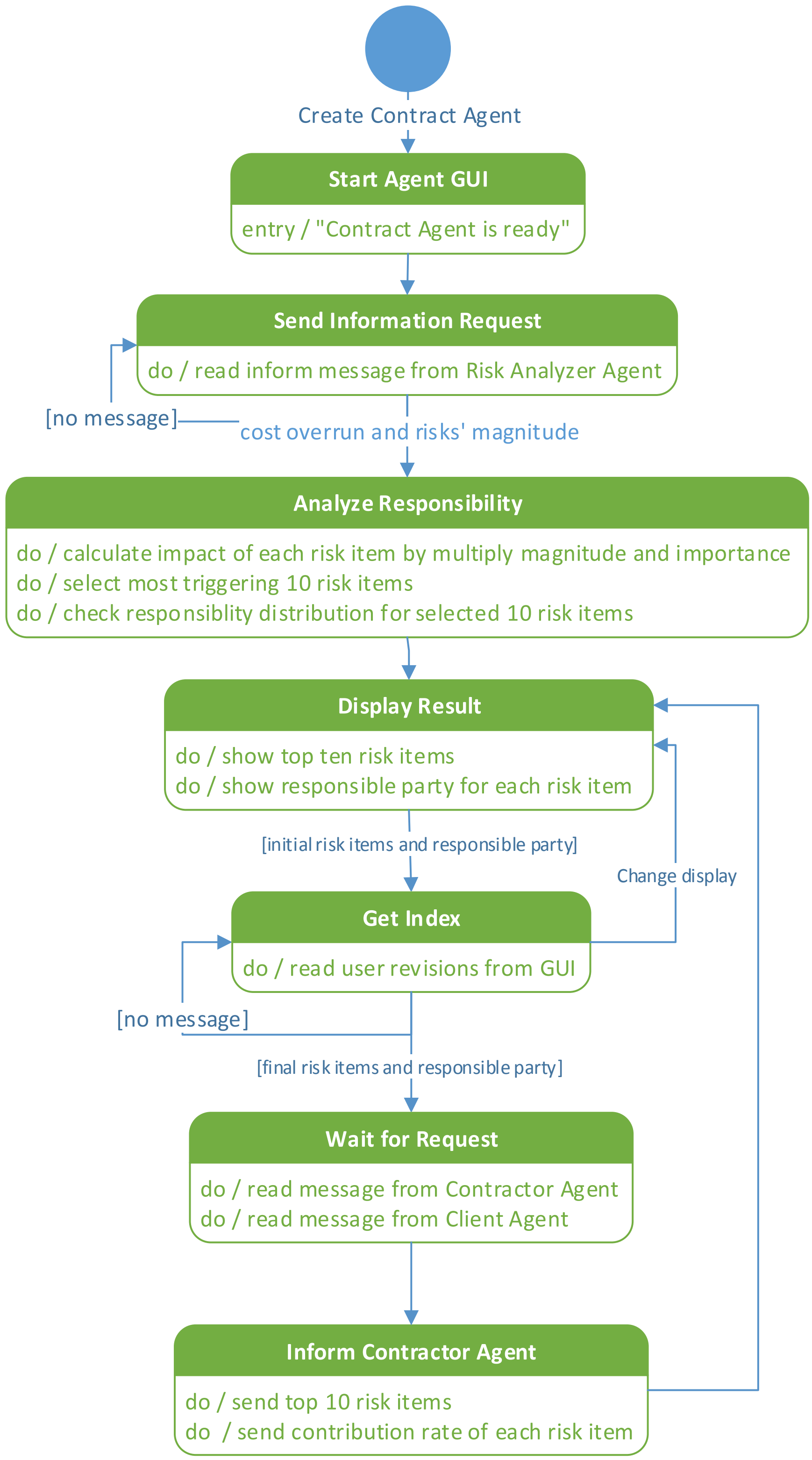

Figure 6.5 State diagram of Contract Analyzer Agent's Behavior

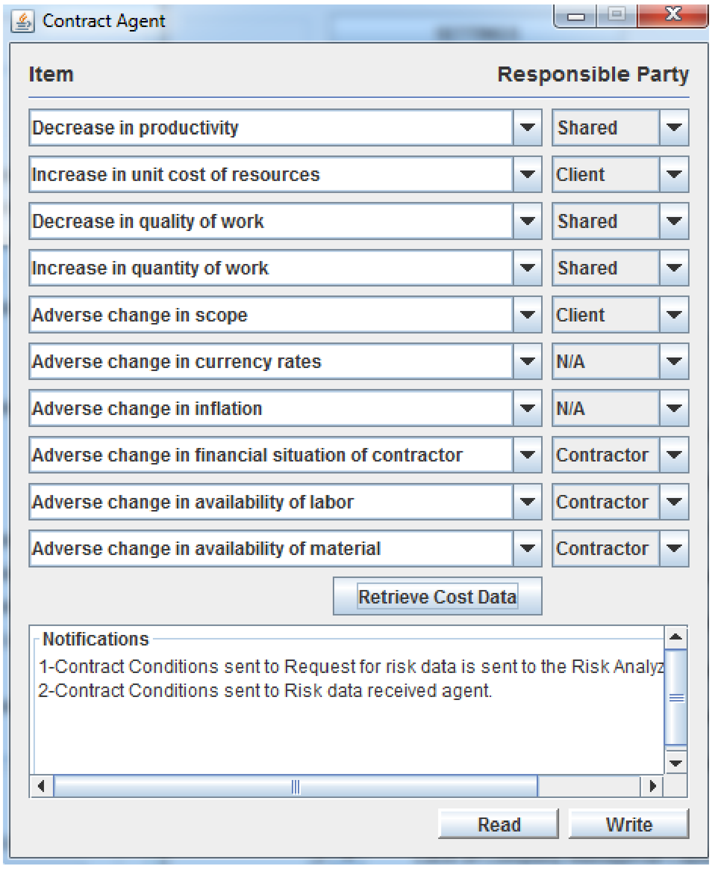

Figure 6.6 Contract Analyzer Agent GUI

6.2.3 Contractor Agent

Contractor Agent represents the Contractor of a construction project and it is one of the main parties in model that takes part actively in bargaining process. Figure 6.7 demonstrates the state diagram of Contractor Agent’s behaviours in multi agent environment.

In addition to main one, Contractor Agent has a secondary GUI (i.e. Risk and Power) (Figure 6.8) that guides the User to request information from other Agents and make necessary inputs for determination of negotiation power of Contractor.

Contractor agent gets cost overrun value and % contribution of risk items on the cost overrun information from the Risk Analyzer Agent and gets the responsible party information from the Contract Analyzer Agent. For the listed power parameters, the User enters rate in 0-100% and the Contractor Agent calculates the level of negotiation power by multiplying rates with importance weights.

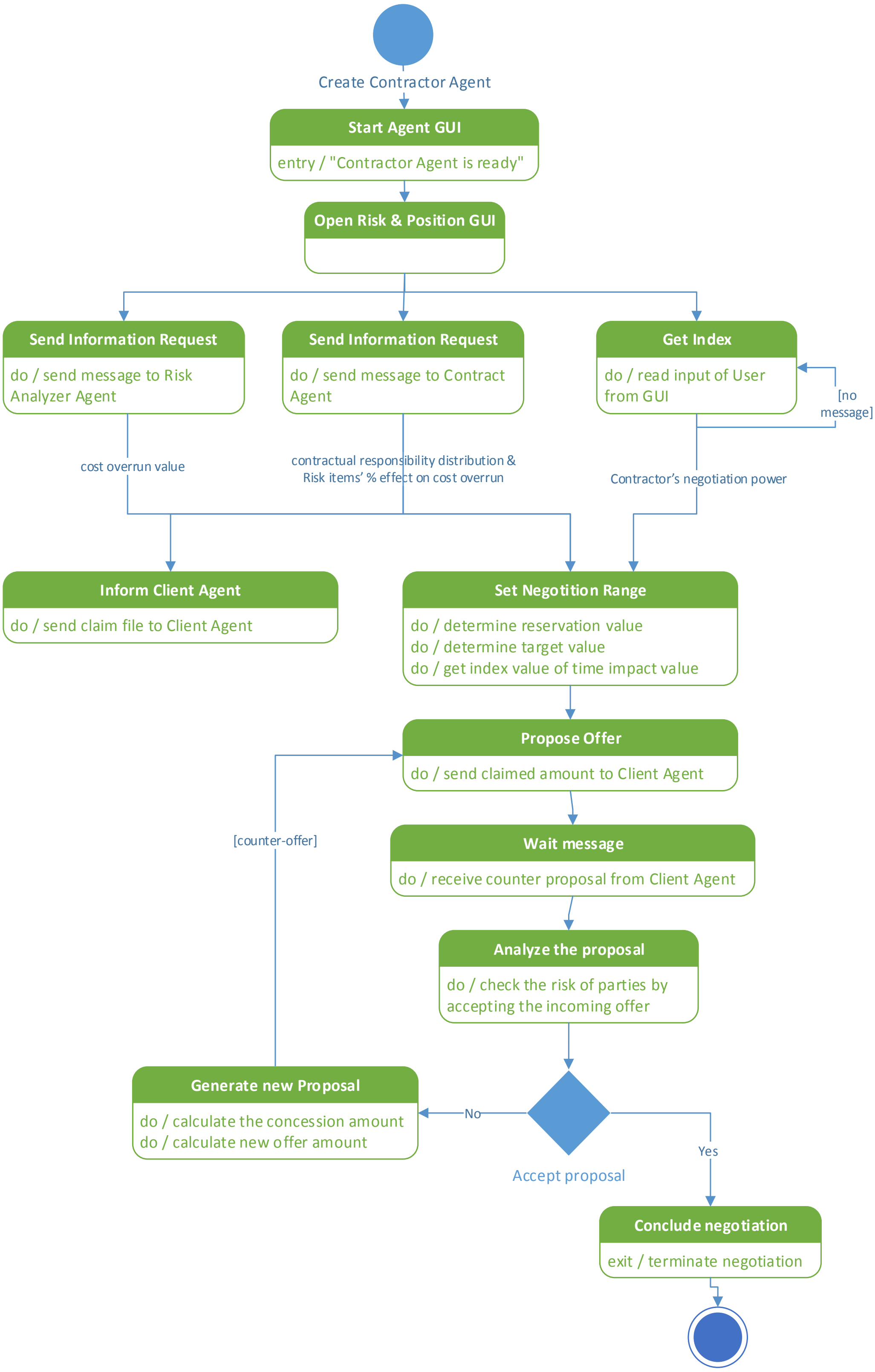

Figure 6.7 State Diagram for Contractor Agent's Behaviors

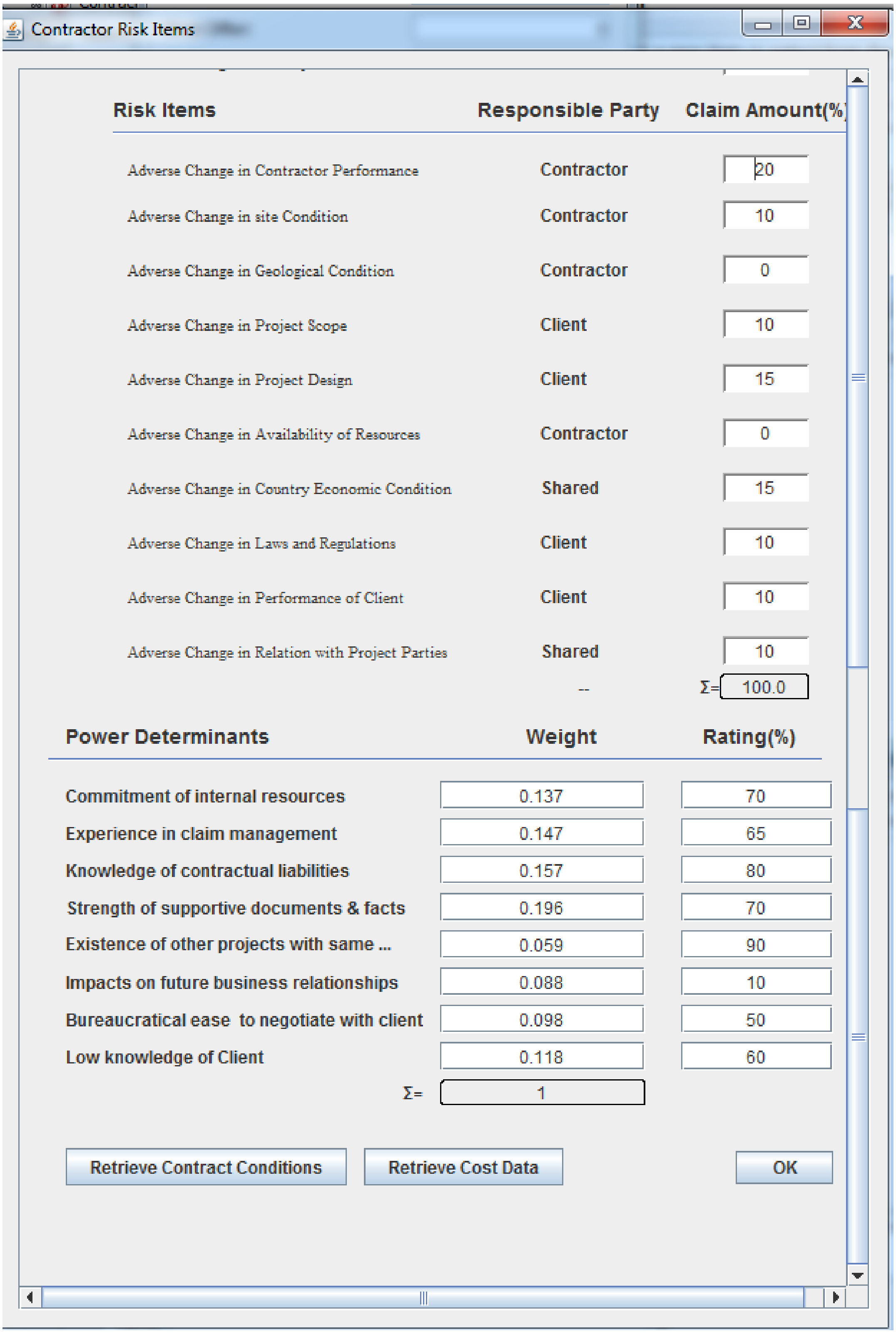

Figure 6.8 Risk and Power GUI of Contractor Agent

After the data entrance is completed, the system turns back to main GUI (Figure 6.9) and demonstrates the automatically calculated negotiation borders. WİTh the “send the claim file” command, Contractor Agents informs the Client agent about the risks, their sharing and cost overrun value due to these risks. With the “send” command, the Contractor Agent’s the initial offer is sent to the Client Agent, which initiates the negotiation process between Client and Contractor. Following offers will be estimated automatically by the Agent through the protocols defined in Chapter 5 of the thesis and proposed to the Client Agent until negotiation finalizes. The steps and output of the negotiation is demonstrated in notifications part of the main GUI. Either agents agree on a distribution or negotiation ends with conflict.

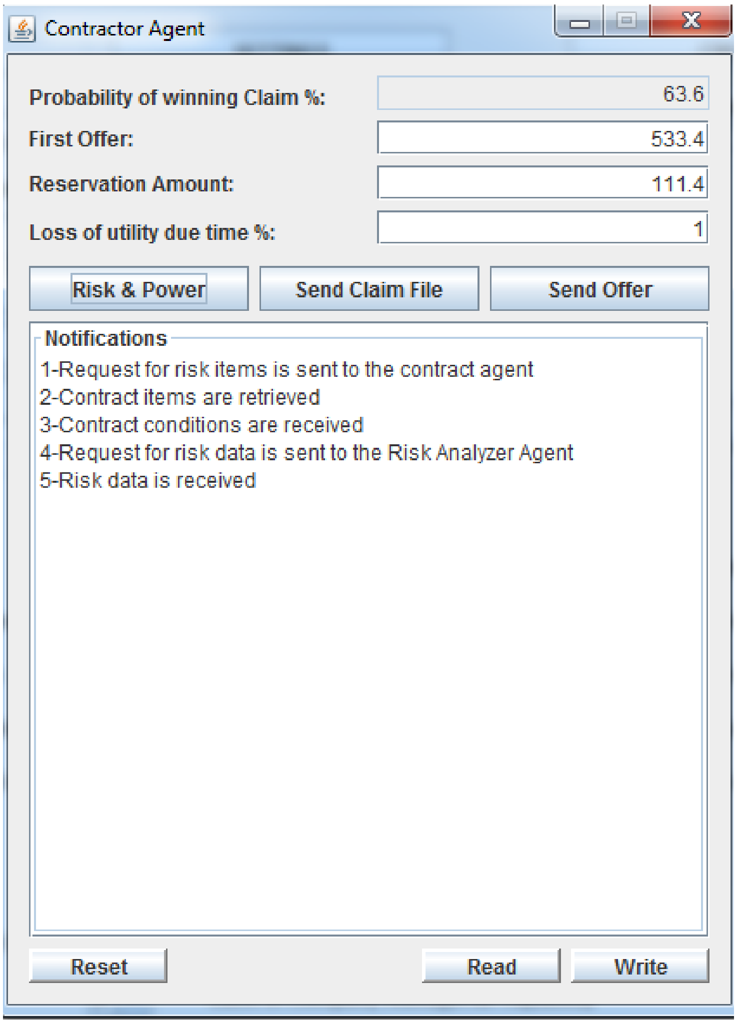

Figure 6.9 Main GUI of Contractor Agent

6.2.4 Client Agent

Client Agent represents the Client's role in construction projects and is the other main party that actively takes part in bargaining process. .

Similar to Contractor Agent, Client Agent has a secondary GUI (i.e. Power) (Figure 6.10) that guides the User to rate the parameters related with Client in order to determine his negotiation power. Client agent gets the necessary information to evaluate the situation from the Contractor agent. Figure 6.11 demonstrates the state diagram of Client Agent's behaviours in multi agent environment

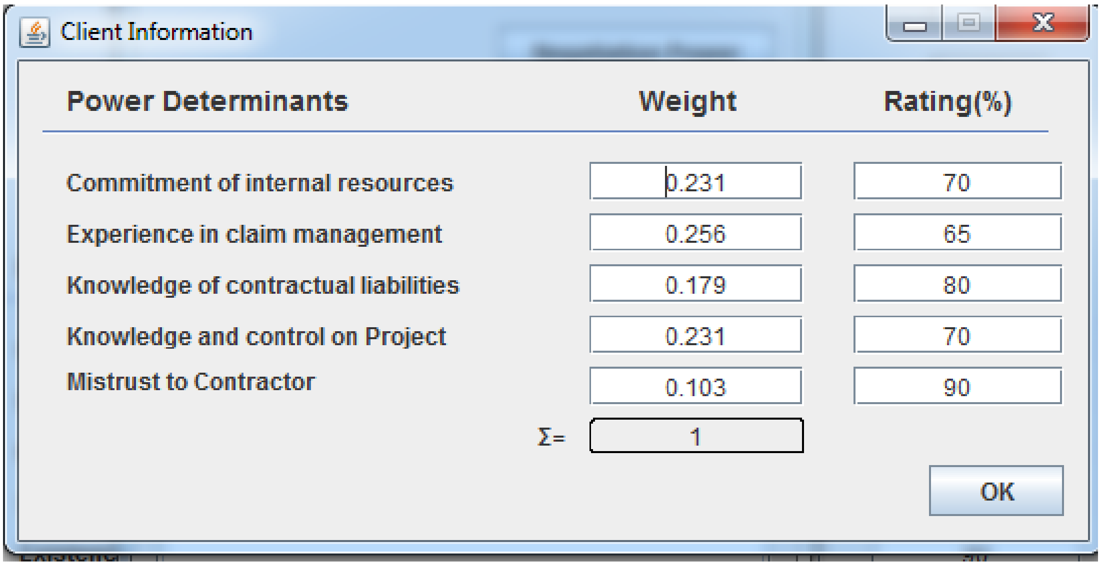

Figure 6.10 Negotiation Power Assessment GUI of Client Agent

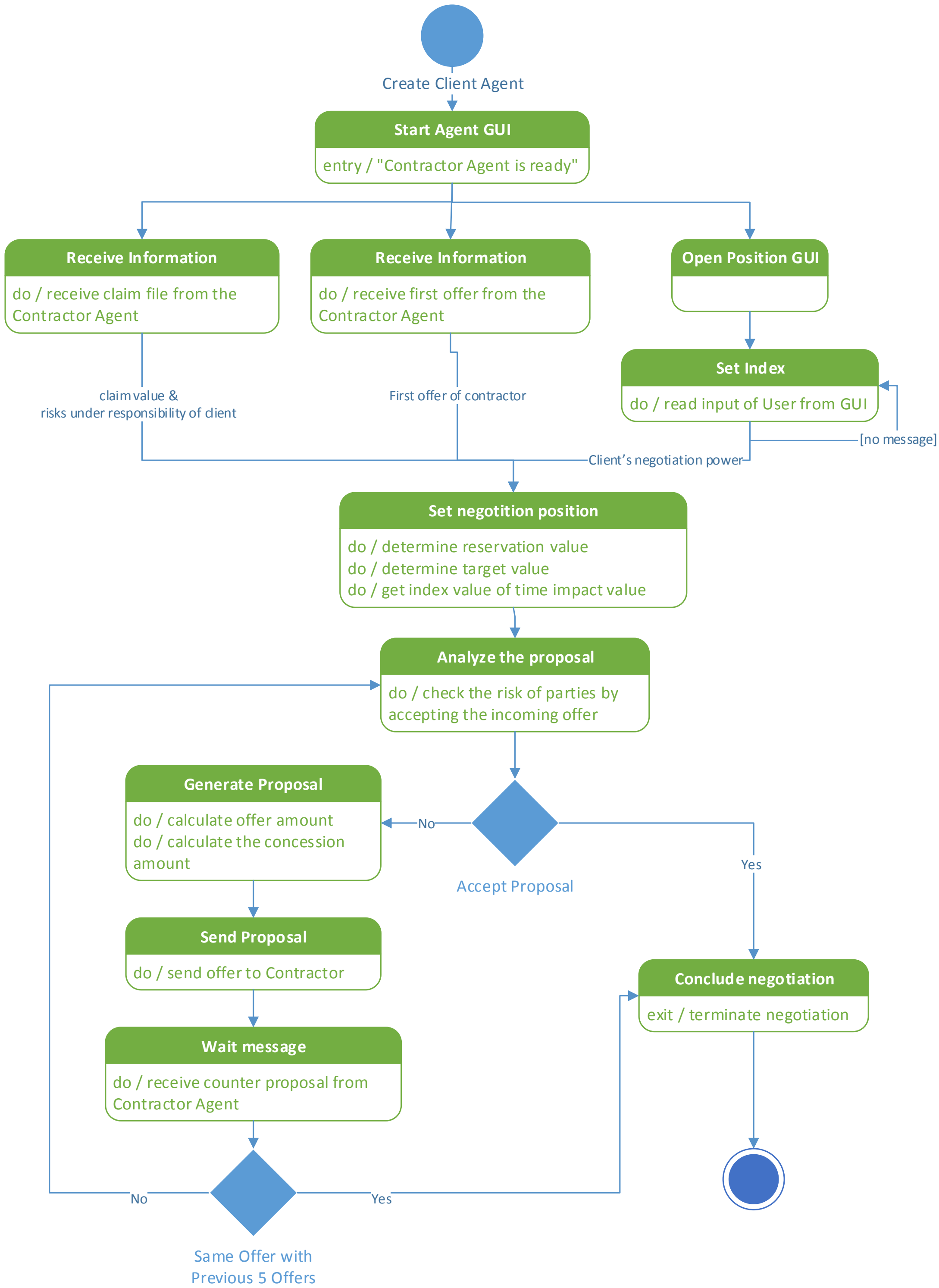

Figure 6.11 State Diagram for Client Agent's Behaviour

After the shaping of negotiation borders they are demonstrated in the main GUI (Figure 6.12) and by following the same rules with Contractor, the offer evaluation and counter offer proposal process is taken place until the finalization of negotiation. Contractor and Client Agents are the ones that finalize the negotiation by accepting incoming offer and terminate the multi agent system. In case same offer is received from Contractor and same offer is submitted by Client for last 5 proposals, it means a deadlock is occurred and parties will not reach to a settlement point. Client terminates the negotiation in case of a deadlock.

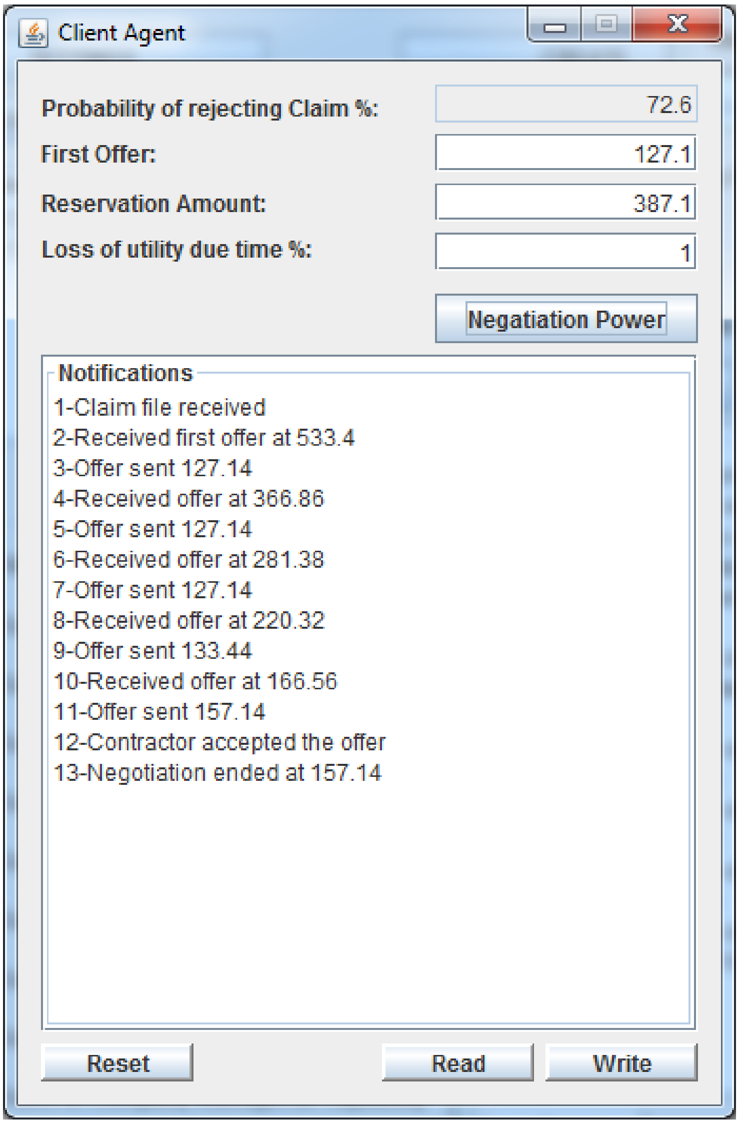

Figure 6.12 Main GUI of Client Agent

6.2.5 Interaction between Agents

Risk analyzer and Contract Agents are responsible from making initial analysis about the project case and provide necessary information to Client and Contractor Agents to shape their preferences. Contractor and Client Agents are the ones directly performing and concluding the negotiation process. The sniffer agent (Figure 6.13) generated by JADE demonstrates the interaction between agents through the process. User interferes in several times to make provide the case specific information to the system.

To sum up the model interactions between user and agents and provide the general view of the multi agent system workflow, Figure 6.14 demonstrates UML sequence diagram of the model.

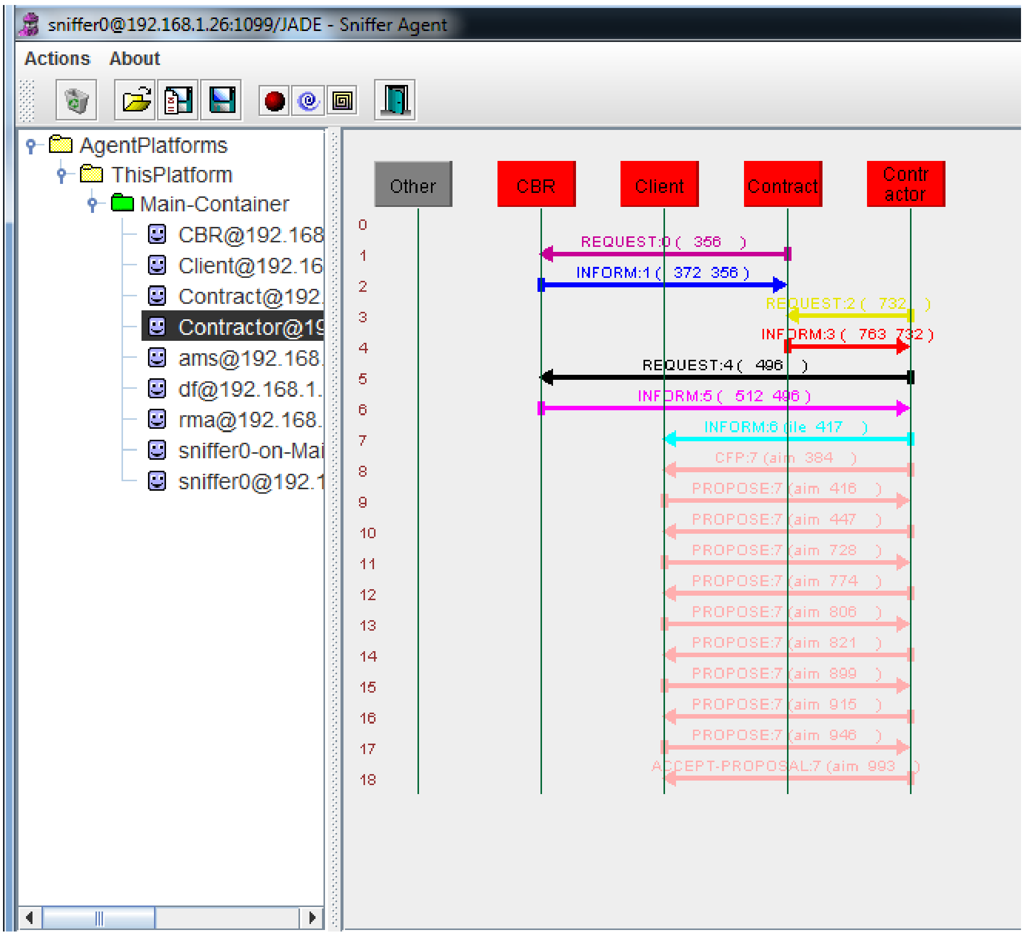

Figure 6.13 Sniffer Agent at JADE to show agent interactions

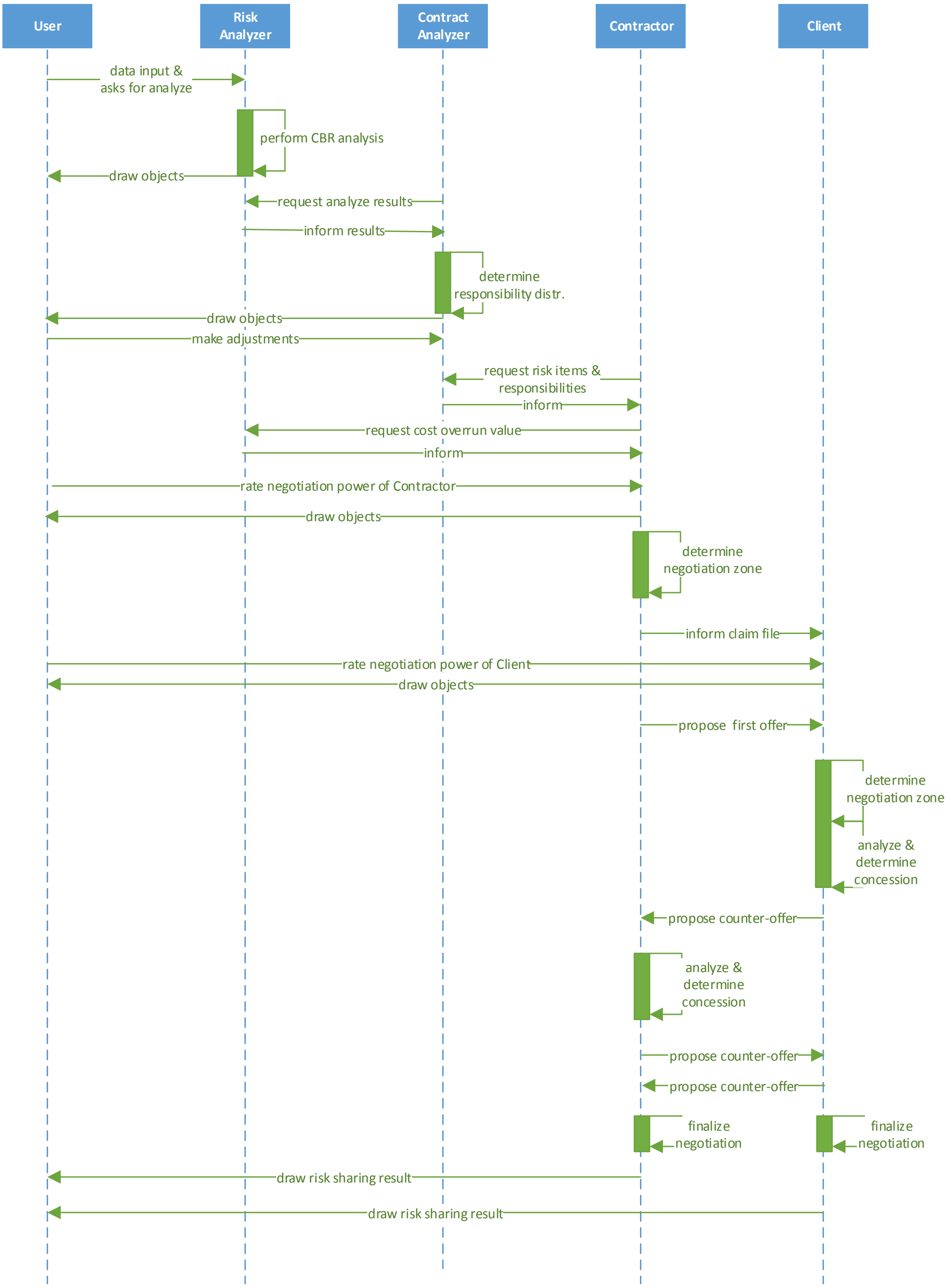

Figure 6.14 Sequence Diagram for User and Agents in Risk Sharing Multi Agent Model

CHAPTER 7

MODEL VALIDATION

A multi agent system is developed within this thesis to establish a systematic way for handling of risk analysis and risk sharing processes in international projects, and to provide a simulation tool for contractors to analyse the risks and their impacts in a project.

To validate the tool whether the model implements the assumptions correctly and whether the assumptions which have been made are reasonable with respect to the real system are questioned. To answer these enquiries, validation is performed in two stages:

- conceptual model validation which checks if agents are modelled in consistency with accepted theories;
- operational validation which ensures the correspondence between model and reality by determining that the model outputs behaviour has sufficient accuracy for its intended purpose and use (Sargent, 1983).

In the first part of this chapter, for conceptual validation, the model is scrutinized through sensitivity analysis. Sensitivity analysis is useful for validating a model, figuring out unrealistic model behaviour, pointing out important assumptions, simplifying a model, detecting critical criteria and identifying drivers (Smith et al., 2008). In the second part of the chapter, for operational validation, through 21 real cases, the behaviour of the system under different project circumstances is investigated.

The outcomes are interpreted together with 4 experts and improvement possibilities are discussed. Knowledgeable people, actively working in international construction management field, are requested to analyse the simulation results to make sure whether the behaviour of the model is reasonable, logic of flowcharts in the model are correct, input-output relationships are rational and the system is useful. The industry practitioners are selected as expert as they are the main end users of the developed system. Selected experts have at least 8 years of experience in international construction projects and all of them have took part in both client and contractor's organizations in different type of projects in different countries. 2 of the experts are currently working as contract managers, one of them is working as project control manager and one of them is working as technical office manager. All the practitioners have experience in project controlling, risk management, claim management, contract management and negotiation.

7.1 Sensitivity Analysis

Sensitivity analysis is formalized through changing the values of the inputs and internal parameters of a model to figure out their effect on the model and the output value (Sargent, 1983). Sensitivity analysis helps to understand the dynamics of the system.

To check whether the multi agent model is in consistency with the accepted theories in literature, a negotiation parameter is changed at each time and its effect on the settlement value is recorded (Figure 7.1). Settlement value is the cost overrun value agreed to be undertaken by client at the end of the negotiation process.

In the base case the settlement point equals to 100.49 (x10^5) USD, contractor reservation and target points are 92.2 (x10^5) USD and 375 (x10^5) USD, client reservation and target points are 163.4 (x10^5) USD and 87.1 (x10^5) USD respectively. The changes in the input variables are analysed by % changes from the base case values.

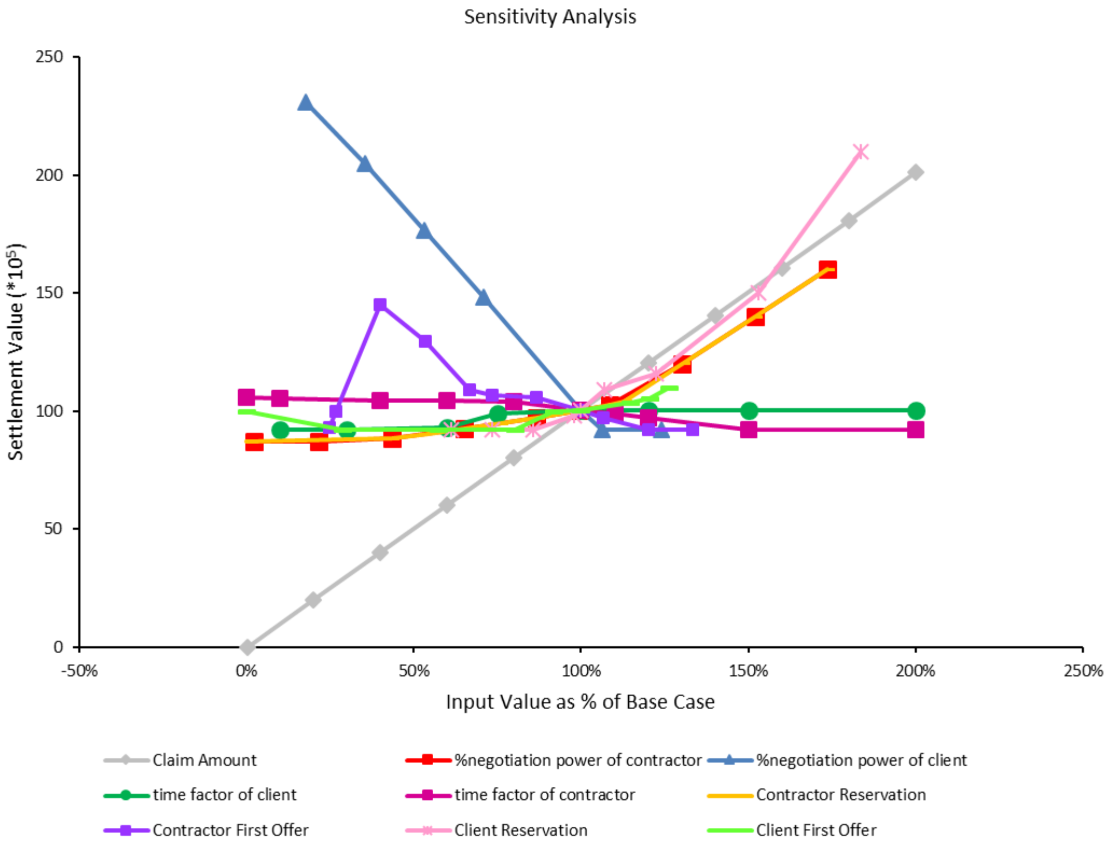

Figure 7.1 Sensitivity Analysis for Settlement Value

The factors significantly effecting the settlement point in favour of contractor are reservation value of contractor, negotiation power of contractor, claim amount and reservation value of client. On the contrary, the main factor against the contractors gain from the negotiation is the negotiation power of opponent party, i.e. client.

Change in negotiation power of the contractor or change in reservation value of the contractor have the same effect on settlement value, due to the fact that, power is one of the main parameters influencing the reservation value of contractor. For smaller reservation values and smaller negotiation power rates, the gain of the contractor is almost same with his reservation value. With increasing reservation value, the settlement value also rises. Once the reservation of the contractor become higher than the reservation of client, the positive negotiation zone disappears and deadlock occurs.

In literature there are some studies that find reservation prices to be an important determinant of the price negotiation outcome (Karakaş et al., 2014; Kristensen and Gaerling, 1997; White et al., 1994; Fisher et al., 2011 and Galloway, 2013) Reservation value is accepted as the lowest outcome a negotiator is willing to accept (Fisher and Ury, 1981). In consistency with the statement in literature (Huber and Neale, 1987; Lim, 1997; Pruitt, 1998; Thompson, 1998; White and Neale, 1994; Yukl, 1974), in the multi agent model developed within this thesis, higher reservation prices lead to better payoffs.

The power rate is a dominant factor in estimation of reservation value (Cheung et al., 2000; Cheung et al., 2010; Russell and Jaselskis, 1992; Kassab et al., 2010; Chan et al., 2006; Moamen, 2009; Fisher and Ury, 1991). When power of contractor upturns, the monetary value of the settlement point also increases. On the contrary, when the negotiation power of the opponent, i.e. client, increases, the settlement value decreases until the reservation value of the contractor and remains constant afterwards.

As stated by Fisher (2005) and Galloway (2013), both negotiating parties should use their power to influence the other, which depends on several factors including the power of skill and knowledge, the power of good relations, the power of defining reservation point and the power of legitimacy. The attributes influencing the power rate are content specific and should be defined by considering the properties of issue under negotiation, negotiating parties and their interrelations. The selection of the parameters defining power rate in construction management field is discussed in detail in research background chapter of this thesis. Accordingly, familiarity with claim case, knowledge on claim procedure, ability to analyse the technical issues, strength of facts, client power, work continuity with client, clients share in contractors works, client negative reaction are selected as the main factors shaping the negotiation process as emphasized by researches including Harmon (2003) and Hoogenboom and Dale (2005).

In addition to settlement value, other significant effect of the negotiation power in the model is related with the number of negotiation rounds. With increasing power, the number of rounds increases, as the contractor becomes more confident with himself and eagers to negotiate to gain more (Figure 7.2). Negotiators with lower power have limited resources to develop constructive alternatives to reach an agreement and therefore they are more dependent on their opponents to settle at a favourable outcome (Bacharach and Lawler, 1980; Pinkley et al., 1994). With increasing power, it becomes less risky for them to take a competitive stance during the negotiation to reach more advantage results (Wang et al., 2012).

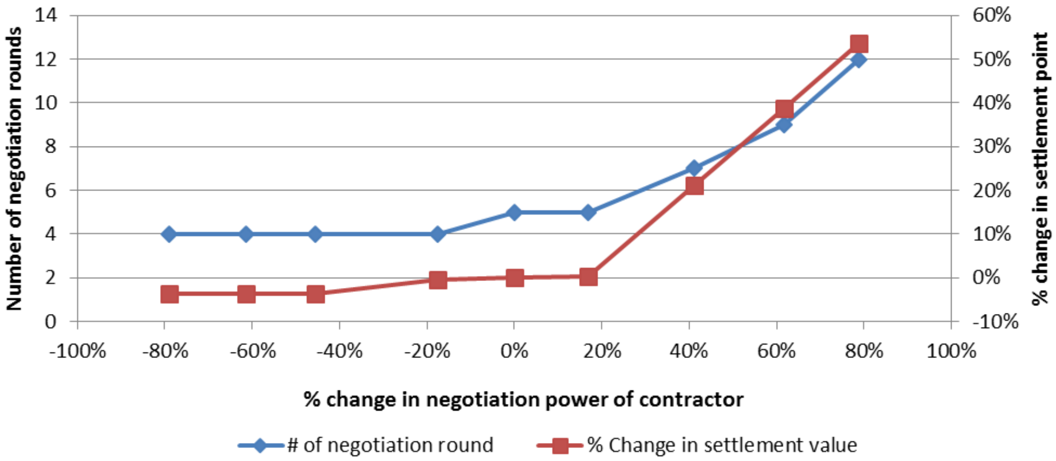

Figure 7.2 Relation between negotiation power, negotiation rounds and settlement

Contractual liability is another important factor effecting the reservation value (Scott and Harris, 2004; Cheung et al., 2011; Cheung and Pang, 2013). The liability difference, existing between parties, exerts an important influence on the negotiation process and outcome. The impact of liability difference is investigated in two separate analysis, with keeping the client % responsibility and shared % responsibility constant respectively. As in the model, agents are accepted to be honest and fair, the contractor agent does not claim the risks that are clearly under his responsibility.

In first analysis (Figure 7.3), the client direct responsibility, in risks generating the cost overrun, is accepted as 0% and all the responsibility is assigned either shared or contractor's responsibility. If the contractor's responsibility equals to 100%, he cannot claim any compensation from the client, as both reservation and first offer of contractor become zero. With decreasing direct responsibility percentage, contractor becomes claiming more and gaining more. However, the reservation value of contractor remains equal to zero in all cases and the settlement value does not increase significantly.

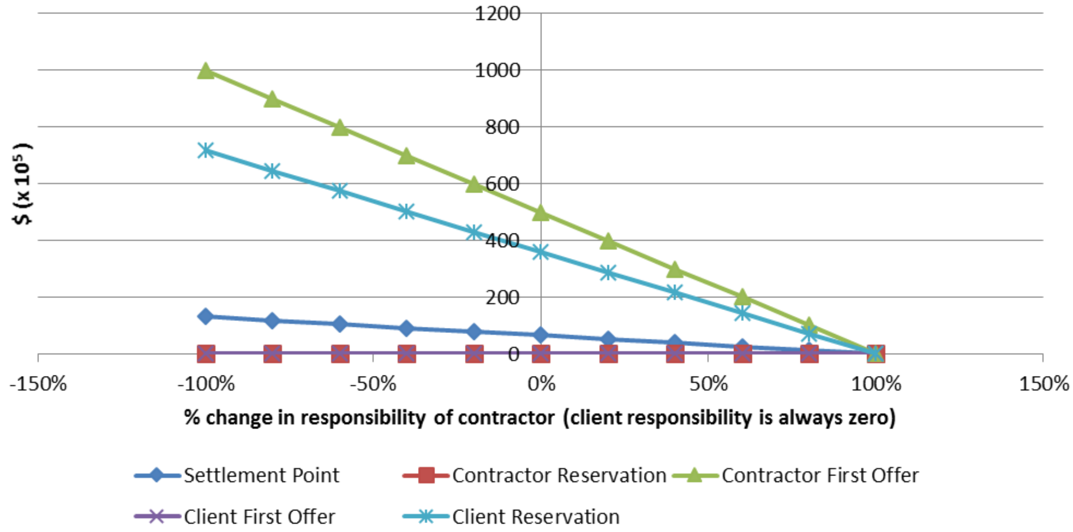

Figure 7.3 Relation between responsibility sharing and settlement by keeping client share as zero

In second analysis (Figure 7.4), the shared percentage is taken as zero, and all the responsibility is distributed between client and contractor. When the client sharing increases, the first offer and reservation value of the contractor also increases and the settlement value is also varies significantly in favour of the contractor. The results indicates that the contractual liability plays a significant role in the negotiation outcome. Moreover, the results also indicate that the reservation value is more dominant impact on negotiation result when compared to initial offer.

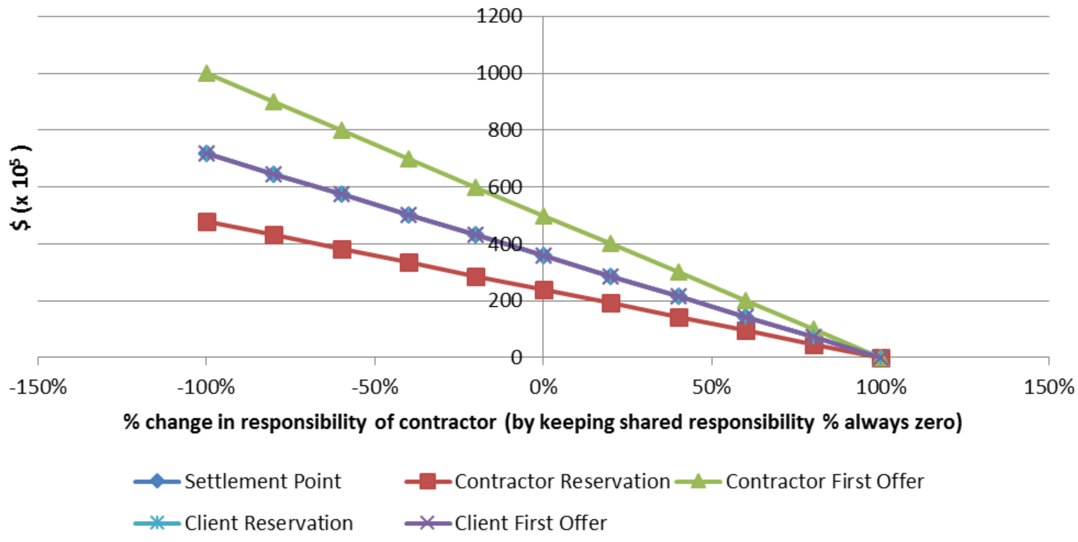

Figure 7.4 Relation between responsibility sharing and settlement by keeping shared % as zero

In literature, initial offer is considered to be an important factor in competitive bargaining processes, as the negotiators with more ambitious goals, i.e. higher target prices reach higher price negotiation outcomes (Huber and Neale, 1986; Huber and Neale, 1998; Lim, 1997; Pruitt, 1981; White and Neale, 1994; Mossmayer et al., 2013). While initial offer increases the settlement value, it should be an optimum value, not too high or low, otherwise it will cause the negotiator to lose (Fisher and Ury, 2005). This is in line with the research results. In Figure 7.1, in the beginning, with increasing initial offer, the settlement value changes in benefit of contractor, however with continuous increase in initial offer, the settlement point starts decreasing.

Figure 7.1 also indicates that time limitation of client and contractor cause fluctuations in the settlement value, although not as significantly as the reservation value and power rate. When the time based utility loss of contractor is increased, the contractors gain decreases. On the other hand, the increasing time limitation factor of client works in favour of contractor by increasing contractor’s gain from the negotiation. Time invested in the negotiations is considered as a special subset of the bargaining cost (Bruner, 2004). Cross (1969) argues that “the more distant the agreement, the less its present value”. Increasing the time penalty forces agents to accept lower settlement values (Karakaş et. al, 2013). In line with the literature, Figure 7.5 demonstrates that in the developed system, increasing utility loss of the contractor forces him to make more concession, accept less amounts in the negotiation and conclude negotiation in a shorter time.

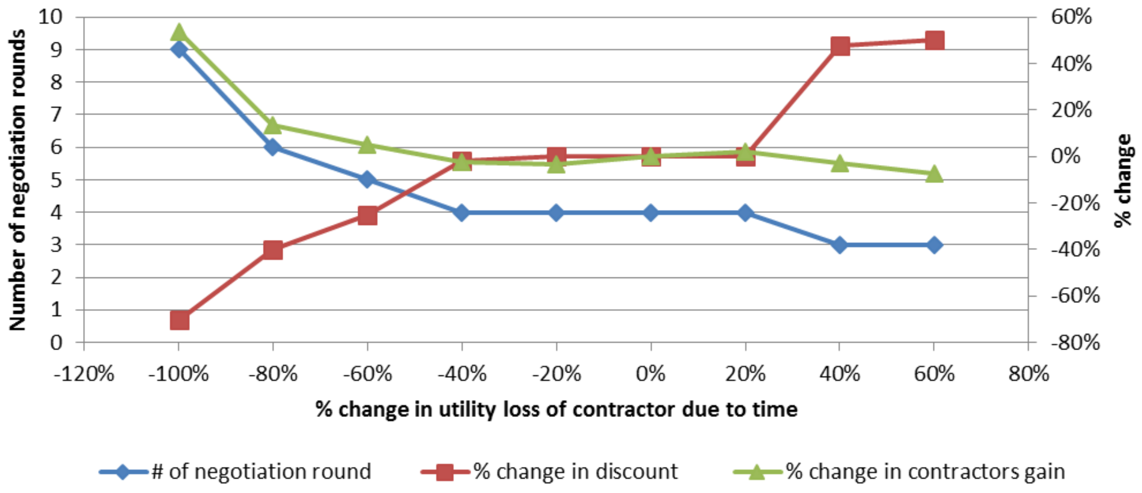

Figure 7.5 Effect of % change in utility loss of contractor due to time

As per to the Figure 7.1, when claim value increases, the monetary value of the contractor's gain from the claim also increases with the same ratio. However, when checked in detail, the gain of the contractor in percentage ratio to overrun cost overrun value remains same (Figure 7.6).

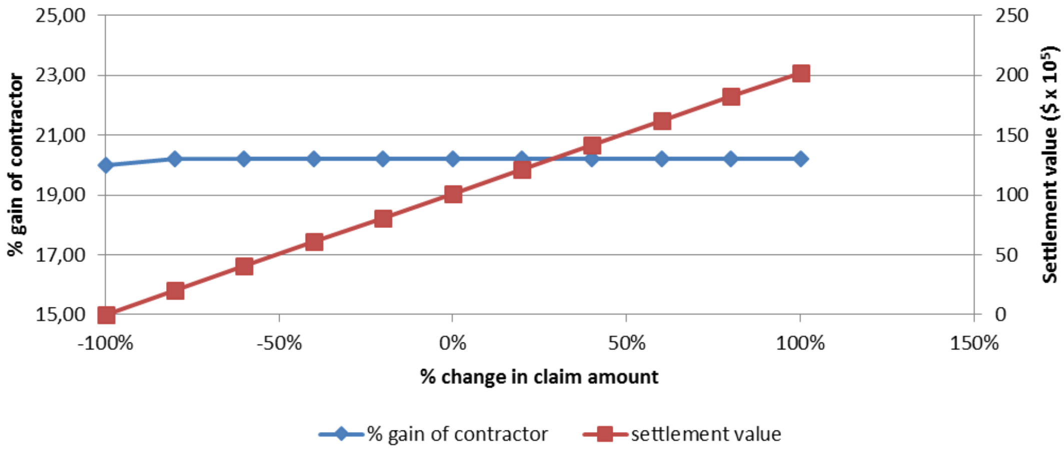

Figure 7.6 Influence of cost overrun value on settlement value

The experts mentioned that, in most of the real practices, the companies also evaluate ratio of cost overrun to their target profits and ratio of real value of losses to claimed cost overrun value. When these rates are significantly high and company believes he has enough economical and technical power to continue, the negotiation process will last longer and contractor will be more be more aggressive to get more from the claim case. However, they all agree that collecting required information about profit rates and real value of the losses will be very challenging, as they are the own know-how the companies. Moreover, experts believe in that once the settlement cannot be reached through the negotiation and the claim amount is a significant value for the company, other dispute resolution methods will be applied, like litigation or arbitration.

Another critical item mentioned by the experts are related with the cultural differences between client and contractor. The communication process can be severely affected by differing cultural conventions, norms, meanings, assumptions and perceptions. As in the system developed within this thesis, the agents are developed as rational by ignoring behaviour and personal aspects, cultural issues are also not considered.

7.2 Real Cases Testing

In order to analyze whether the developed multi agent system's behavior is in line with the reality, system is tested with 21 real cases data. The cases are selected from the ones initially used in development of risk event database by paying attention to select international projects undertaken by different companies in different countries. The projects are selected by considering the status of negotiation process. In order to be an appropriate case for testing, the projects and the claim negotiation process need to be finalized. In addition to the initial vulnerability and risk related information, the main risks causing deviation in budget, cost overrun value and cost overrun sharing percentages agreed by the project parties are requested from the companies.

By using the previously consulted experts, who are familiar with the ontological structure and terminology of the model, the errors to be faced in data collection stage are tried to be minimized.

The summary of the real case data are given in Table 7.1. The cases have different combinations of contract types, payment types, project types and cost overrun percentages, which make possible to analyze suitability of system behavior under different circumstances.

Table 7.1 Summary of Real Cases

No.	Type	Duration (month)	Contract Type	Delivery system	Payment Type	Company Role	Region	Cost Overrun Rate (%)	Negotiation Outcome (% of Risks Undertaken by Client)
1	Indust.Plants	34	Local	Turnkey	LumpSum	Sole Contractor	Suudi Arabia	41	27
2	Energy	32	Local	Turnkey	LumpSum	Consortium Partner	Turkey	20	0
3	Transportation	24	FIDIC	Turnkey	UnitPrice	SoleContractor	Albania	25	0
4	Other	18	Local	Turnkey	LumpSum	Subcontractor	Libya	10	0
5	Transportation	24	Local	Traditional	UnitPrice	Subcontractor	Libya	30	0
6	Indust.Plants	96	Local	Traditional	UnitPrice	Subcontractor	Kazakhstan	25	50
7	Infrastructure	24	FIDIC	Turnkey	CostPlusFee	SoleContractor	Romania	15	20
8	Energy	33	FIDIC	Turnkey	LumpSum	ConsortiumPartner	Macedonia	5	0
9	Buildings	21	FIDIC	Turnkey	LumpSum	SoleContractor	U.A.E	25	40
10	Transportation	12	Local	Turnkey	UnitPrice	SoleContractor	U.A.E	20	60
11	Infrastructure	24	Local	Turnkey	LumpSum	SoleContractor	Afghanistan	5	15
12	Transportation	24	Local	Traditional	UnitPrice	SoleContractor	Libya	40	60
13	Housing	19	FIDIC	Turnkey	LumpSum	SoleContractor	U.A.E	40	5
14	Dams	48	Local	Other	Other	SoleContractor	Turkey	20	20
15	Other	36	FIDIC	Turnkey	LumpSum	SoleContractor	Ukraine	55	40
16	Buildings	16	FIDIC	Turnkey	Other	SoleContractor	Russia	5	20
17	Dams	30	Local	Turnkey	LumpSum	SoleContractor	Libya	35	25
18	Indust.Plants	22	FIDIC	Turnkey	LumpSum	JV Partner	Jordan	25	20
19	Other	36	FIDIC	Turnkey	LumpSum	ConsortiumPartner	Libya	10	0
20	Buildings	33	FIDIC	Turnkey	LumpSum	SoleContractor	Qatar	20	10
21	Pipelines	36	Local	Traditional	UnitPrice	JV Partner	Libya	15	0

Since the system does not aim to make a precise estimation, the aim in real case testing is also not to show how precisely the model estimates the cost overrun value, or the rate of responsibility to be undertaken by project parties in cost overrun sharing. Either, the real case validation aims to analyze the tendency of the model estimations with compared to real project data to show the usability of model.

To validate the closeness of the model to reality, the main indicator is selected as the tendency in cost overrun rate undertaken by project parties. The real case cost overrun sharing percentages and the simulation results are compared under three categories by considering the main party undertaking the highest ratio of the cost overrun: contractor undertakes more (negotiation outcome is between 0%-33%), client and contractor share equally (negotiation outcome is between 34%-65%), client undertakes more (negotiation outcome is between 66%-100%).

While the aim is not to make precise estimation, to support the confidence level of the model with reality, the success of multi agent model in estimation of similar risks items with the real case and multi agent model, similar cost overrun value and similar cost overrun values undertaken by parties are also examined.

Similar risk items are questioned through the comparison of top ten risks identified by the model and stated by the experts during data collection. Cost overrun percentage (cost overrun divided by overall project cost) and negotiation outcome, which indicates the percentage of cost overrun undertaken by the client, are testified to understand their similarity with real data.

The comparison results of multi agent system and real cases are given in Table 7.2

Table 7.2 Comparison of Multi Agent System and Real Cases

Case	Real Case Results			Multi Agent Model Results			Comparison of Results			
	Cost Overrun value (Real) (%)	Cost overrun value undertaken by Client (Real) (%)	Main party undertaking the highest ratio of cost overrun (Real) (%)	Cost overrun value (Model)	Cost overrun value undertaken by Client (Model) (%)	Main party undertaking the highest ratio of cost overrun (Model) (%)	Number of similar risk items identified in real case and model	Absolute difference between cost overrun values (%)	Absolute difference between contractor gain values (%)	Similarity of main responsible party category
1	41	27	contractor	40	9,30	contractor	7	1	17,70	same
2	20	0	contractor	20	0,00	contractor	8	0	0,00	same
3	25	0	contractor	20	11,20	contractor	7	5	11,20	same
4	10	0	contractor	10	11,73	contractor	6	0	11,73	same
5	30	0	contractor	40	10,50	contractor	6	10	10,50	same
6	25	50	equal	10	23,58	contractor	4	15	26,42	not same
7	15	20	contractor	10	32,93	contractor	5	5	12,93	same
8	5	0	contractor	10	9,33	contractor	6	5	9,33	same
9	25	40	equal	25	13,98	contractor	6	0	26,02	not same
10	20	60	equal	20	12,67	contractor	8	0	47,33	not same
11	5	15	contractor	10	10,30	contractor	4	5	4,70	same
12	40	60	equal	40	27,92	contractor	6	0	32,08	not same
13	40	5	contractor	35	5,59	contractor	6	5	0,59	same
14	20	20	contractor	10	11,94	contractor	7	10	8,06	same
15	55	40	equal	40	37,46	equal	7	15	2,54	same
16	5	20	contractor	10	10,46	contractor	6	5	9,54	same
17	35	25	contractor	20	8,06	contractor	6	15	16,94	same
18	25	20	contractor	20	11,62	contractor	6	5	8,38	same
19	10	0	contractor	10	2,37	contractor	6	0	2,37	same
20	20	10	contractor	20	11,24	contractor	8	0	1,24	same
21	15	0	contractor	20	8,71	contractor	7	5	8,71	same

The average similarity between the top ten risk items rooting the cost overrun is calculated as 6.3 out of 10. When the cases with lowest similarity rate (cases 6, 7 and 10) are investigated, it is figured out that during this three projects an unexpected event (i.e. existence of social unrest/disorder, existence of strike/labor problem and rebellion /terrorism) is reported as an important issue influencing variance in project cost. The existence of an unexpected issue decreases the probability of accurate estimation of main risk items by using vulnerability data reflecting the early stage of a project.

The average error in cost overrun percentage estimation is 5.05%. Since the cases used in validation are the ones already existing in risk event database, used for the formalization of case-based reasoning model (risk analyzer agent), the average error in cost overrun estimation is observed as very low. 16 out of the 21 cases (76% of cases), the cost overrun percentage is under the average error rate. This indicates that the risk analyzing model is formalized correctly and behaves in consistency with the reality.

When the cases under and over the average error rate are investigated, it is observed that the average number of similar risk items are higher in cases under the average error rate. The average number of similar risk items identified in model and given in real data are 6.38 for the cases under the average error rate, while it is 6.0 for the cases over the average error rate. This reveals out the fact that the correct identification of risks are important for the correct estimation of cost overrun.

According to the comparison results, the average error in responsibility sharing percentages is 12.8 % on average. 14 cases out of the 21 cases (66.6 %) are under the average error rate. The average number of risk items identified correctly are 6.43 for the cases having less error rate, while the average number is 6 for the cases having more error rate than average. While correct identification of risk items are not directly linked with the risk sharing percentage in the model, it forms the basis for responsibility distribution defined by contract agent in the model.

One other basis of the responsibility distribution is the contract type, which is grouped as either FIDIC or local regulation in the data set. 10 out of the 21 cases have FIDIC type contract. The analysis results reveal out that 8 of the 10 projects having FIDIC contract have less error than average in responsibility sharing percentages. While this ratio does not show a significant difference for local type contracts, 6 of 11 cases are in less error category. Since the FIDIC contract type is accepted to be more comprehensive in defining risks and responsible parties, the comparison results show that the model works in line with real life cases. Moreover, the results indicate that the basic responsibility distribution in FIDIC, provided for the system users within the multi agent model, is capable enough to direct the users in correct manner to assess the liabilities.

When the tendency of the system in responsibility sharing categorization is studied, through the multi agent model analysis, 17 cases (over 21 cases) are listed under the same responsibility category as they are in reality, which corresponds to 81% percent.

The comparison of the multi agent system outputs and the real cases are discussed with the experts and all of them are at the same opinion that error rates of the model are low enough to make the model confident and usable in showing the tendency of real project cases. The identification of risks correctly and assessment of responsible parties are defined as the most crucial part of the risk consequence sharing process by the experts. Therefore, they are likeminded the system makes it easier for the contractors to handle these issues. Moreover, the sub-stages of the model provides a valuable guidance for the contractors to show the risk and related claim management processes. However, in the model the assessment of power rates and time factor are found to be subjective by the experts, which decreases the reliability of the system. The experts recommend to put a description part and scale, to guide the users in assessment of these rates to make the assessment more objective.

CHAPTER 8

CONCLUSION AND FUTURE WORK

In construction management literature, while there are several studies aimed to develop a mechanism for risk management, decision making and dispute resolution, none of them are sufficient enough to cover all parts of the risk management and negotiation processes to provide a realistic risk-budget sharing model on their own. This thesis has presented a new structure to fill this gap in literature by developing an integrated and coherent system for analysis and sharing of risk impacts by combining multi agent system and risk management principles.

Through the study carried out under this research, a multi agent system (MAS) is developed, which simulates the risk analysis process and risk sharing negotiation between project parties to reach an agreed responsibility distribution. The vulnerability sources, risk paths happened throughout the project, impact of risk on project budget, and contract conditions forms the basis of the negotiations in addition to the expectations and preferences of the parties.

The developed model has three main advantages when compared to similar systems:

1. In current risk analysis model, usually, risk are defined in a hierarchical manner according to their sources and the interrelations among the risks are ignored. Within this thesis, a formal ontology for relating risk and

vulnerability with cost overrun. Ontology provides a common vocabulary which forms the main framework of an information model for risk assessment in international projects. Such a common vocabulary upholds the focus on the most important concepts of risk and vulnerability domain related with cost overrun. The ontology shapes the basic structure of a risk event history database. It proposes a complete glossary of notions with their interrelations that should be included in the database. Moreover, it outlines the integrated risk and vulnerability assessment method to be used for cost overrun estimation in international construction projects.

2. Most of the current risk analysis applications in literature rely on probability theory that models the risk and impacts through probability distributions. In these models, the randomly assigned probabilities forms the basis of the scenarios and it is usually unclear to identify the circumstances generating the outcome. However, instead of randomly assigned values, the system developed under this thesis relies on the experience of the Turkish Contractors in international market. Post project information regarding various international projects, which is collected via the ontological model and stored in the ontology-based database structure, are used to predict cost overruns and possible risk paths in forthcoming projects by case-based reasoning. The outcome of the prediction model is used as the basic input of multi-agent system.

3. In current multi agent models in construction management literature, while modelling the negotiation process, the risk sharing principles, contract clauses, strengths, short and long term preferences of the negotiating parties are usually not considered. However, while modelling negotiation process, the right description of project parties having different properties and target as well as the negotiation rules and environment are required. In the multi agent model developed within this

thesis, the communication platform is modelled by considering these requirements. And, the final impact analysis of risks and the responsibility sharing among parties are handled with a more comprehensive environment.

The most important contribution of the developed multi agent model will be that the contractors carrying out international projects will be able to identify risks at the start of a project, to estimate their impacts by creating possible risk scenarios, to bid and contract by considering the risk magnitudes and to formulate effective risk management strategies. Since the main reasons of disputes in international construction projects are the poor risk identification and analysis, it is believed that the MAS-based risk estimation, risk allocation and cost overrun sharing environment will increase the success of contractors significantly.

Moreover, the risk event database will improve the decision making process of contractors by providing information on past cases. The database will not only be useful for the estimation of cost overrun, but will also support learning from previous risk events. By using the ontological structure, contractors will store their own experiences and establish their own databases to make more accurate analysis.

The verification and validation tests are undertaken to figure out the reliability and the confidence of the developed model by comparing with literature and real cases. The comparison results and possible improvements are analyzed with sector practitioners.

To verify the model, sensibility analysis is performed to understand the impact of each parameter on system outcome. The sensitivity analysis showed that the parameters effect on the risk sharing percentage are all parallel with the widely accepted facts in literature, which proves that the model is properly formalized.

According to analysis results, the most important factors influencing the responsibility sharing among parties are the reservation values of the parties which are shaped mainly by the contractual liability and negotiation power rates of the parties. As recommended by several researches, the model supports to start bargaining with optimum target, very high or very low offers causes the contractor to lose money. While time limitation and time related loses of the parties are not very important markers in terms of responsibility sharing, they makes the parties to compensate more at each round of the bargaining process and results in losses for long-lead negotiations. While increase in cost of the project results in increase of the settlement value, it does not make any difference when the results are investigated in percentages. However, the experts recommend that to improve the results and compliance with real applications, the ratio of the cost overrun value with the profit of the contractor and with the real cost of the claimed risks will be also considered in the model as they will influence the reservation values. Moreover, the experts recommend to add cultural similarity as a factor in the model, as it influences the norms and rules of communication among parties.

To validate the model, secondly, the model is tested with 21 real cases, which are all completed international projects. The main outcomes of the model (i.e. the most crucial risk items, cost overrun rate, cost overrun sharing rate and the party undertaking the main portion of the cost overrun) are compared with the real case results. While the model does not aim to make precise estimation of the risk sharing process outcomes, the analysis revealed out that the model behavior is in line with the model is confident enough to guide the users. The results revealed out that the most crucial parameter in correct determination of the risk impact and risk sharing results is the precise estimation of the risk items. Both the error rate in cost overrun estimation and in cost overrun sharing percentage are less in the cases where risks are determined more accurately. Moreover, for the cases that the contract clauses are more clear and renowned, the difference between responsibility sharing percentage estimation of the model estimation and the real case decreases. The comparison of the multi agent system outputs and the real cases are discussed with the experts and they are like minded that the results are logical and the error rates of the model are low enough to make it confident and usable enough in analysis of risks in construction projects. To increase the usability and reliability of the model, experts recommend to add a scale for assessment of the power rates and time based utility loss levels. Since these parameters are subjective rates decided by the user, it will cause them to enter misleading inputs.

Validation tests provide evidence that the multi agent risk sharing system successfully relates risk and vulnerability with cost overrun, formulates parameter influencing the responsibility sharing process and estimates the risks, cost overrun values and cost overrun sharing rates. The developed system is reliable and usable enough to simulate the risks and their impacts in international construction projects.

The existence of the real cases in the risk event database is the shortcoming of the validation process. However, the case base reasoning model, used to predict the risk consequence, has already been validated through cross validation methodology in earlier stages of this research project. Therefore, the aim of the validation test in this study is not to validate the CBR model again, but to understand how the agents behave under different circumstances. The usage of the same cases eliminates the errors in data collection stage and minimizes the errors in inputs of the multi agent model. Moreover, the usage of the similarity in estimation prevents the model to begin to memorize and prevents over fitting. The minimization of errors in inputs multi agent model makes it possible to understand better how the multi agent system works.

In further stages of this study, the performance of the model may be improved through formalization of more specific risk event databases, inclusion of cultural and cost overrun ratio related parameters into the model and addition of descriptive scales for more objective assessment of power rates of the parties.

The model developed consists agents that can interact with each other cooperate in problem solving. In the developed model there are four agents. Two of these agents (risk analyzer and contract agents) mainly process the data on their own and share their outcomes only once with the other agents. The remaining two agents (client and contractor agents) continuously share the data they have processed with each other until reaching a settlement. While in the core case, the negotiation process takes place between client and contractor, there are several cases that require the involvement of designer, subcontractors, joint ventures, sponsors or other clients in the negotiation process. The model developed in this thesis allows the integration of new agents into the model. Therefore, the system may be adapted to simulate the more complex cases by the addition of other cooperative agents into the system.

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B.S.	METU Department of Civil Engineering	2006
High School	Gazi Anatolian High School	2001

PROFESSIONAL EXPERIENCE

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2012-2014	Astaldi-Türkerler JV, Etlik Integrated Health Campus Project, Ankara,Turkey	Planning Engineer
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2010-2011	Summa A.Ş., Abou Nawas Resort Hotel Project, Tripoli, Libya	Technical Office Engineer
2010-2010	MİTAŞ Energy and Metal Construction Inc., Ankara, Turkey	Project Control Engineer
2007-2010	Middle East Technical University, Ankara, Turkey	Research and Teaching Assistant
2006-2007	MİTAŞ Energy and Metal Construction Inc., Ankara, Turkey	Design and Scheduling Engineer

PUBLICATIONS

1. Fidan (Dağkıran), G. (2008) A risk and vulnerability ontology for construction projects, MS Thesis, Department of Civil Engineering, Middle East Technical University, Ankara, (Supervisor: Prof. Dr. İrem Dikmen TOKER) Dikmen, I., Birgonul, M.T., Fidan(Dağkıran), G. and Ozcan, G. (2008), "A Risk and Vulnerability Ontology for Construction Projects", PM-04 - 4th SCPM and 1st IPMA/MedNet Conference "Project Management Advances, Training and Certification in the Mediterranean", 29-31 May 2008, Chios Island, Greece, pp.137-142.
2. Dikmen, I., Birgonul, M.T., and Fidan(Dağkıran), G. (2008), "Assessment of project vulnerability as a part of risk management in construction", in: Carter, K., Ogunlana, S., and Kaka,A. (Editors) Procs. Of Joint 2008 CIB W065/W055 Symposium, 15-17 November 2008, Dubai, United Arab Emirates.
3. Dikmen, I., Birgonul, M.T., and Fidan(Dağkıran), G. (2009), "A Risk and Vulnerability Ontology for Construction Projects", International Journal of Engineering and Management, Vol.1 (1), page 63-70.
4. Fidan(Dağkıran), G., Dikmen, I., and Birgonul (2010), M.T, "Using Multi Agent Systems in Construction Claim Negotiation", ICCCBE2010, The International Conference on Computing in Civil and Building Engineering, 30 June - 2 July 2010, Nottingham, England.
5. Dikmen, I., Birgonul, M.T., Fidan(Dağkıran), G. , Eybpoosh, M. and Karakas, K. (2010), "Çok Aracılı Maliyet Tahmin ve Risk Paylasım Sistemi", 1. Proje ve Yapım Yönetimi Kongresi, ODTÜ Kültür ve Kongre Merkezi, 29 Eylül-1 Ekim 2010, Ankara.
6. Fidan(Dağkıran), G., Dikmen, I., Tanyer, A.M. and Birgonul, M.T (2011), "An Ontology For Relating Risk And Vulnerability With Cost Overrun In International Projects", ASCE Journal of Computing in Civil Engineering.

CERTIFICATES AND SCHOLORSHIPS

1. Training ceritificates on Project Management; Contract Management and MS Project Applications for Project Management, Rönesans Değişim ve Yönetişim Bilimleri Enstitüsü, July 2010.
2. ISO 9001:2000 Quality Control System, Intern Investigator Certificate, TSE, 2007
3. Research Scholorship by TUBİTAK between 11.2007-03.2010
4. Best conference paper in “Project Management Advances, Training and Certification in the Mediterranean” Conference, 29-31 May 2008, Chios Island, Greece
5. Dean’s Honor List: 2005 Spring Term; 2005-2006 Fall Term; 2005-2006 Spring Term

FOREIGN LANGUAGES

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