ANALOGICAL REASONING FOR RISK ASSESSMENT AND COST OVERRUN ESTIMATION IN CONSTRUCTION PROJECTS

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ABSTRACT

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Project cost increase is the main concern in international construction projects which usually results in disputes and conflicts among the project participants. The aim of this thesis is to construct a database that represents risk event history regarding international construction projects and construct a cost overrun prediction model. It is hypothesized that magnitudes of project related, company related and country related risk factors can be predicted by assessing the level of vulnerability by analogical reasoning with previous projects. The vulnerability and risk factors can further be used to predict cost overrun in the bid preparation stage of international construction projects. Thus, prediction models that link vulnerability with risk factors and cost are constructed by using a dataset of 166 international construction projects, which consists of 66 real and 100 hypothetical cases. Case-based reasoning (CBR) technique is used to construct the prediction models. After testing the performance of various CBR models using different weight generation and retrieval methods, error rate of +/- 7.15 % cost increase is achieved. The utilization of CBR models in the prediction of potential risk sources and cost overrun is demonstrated by a real case study. Finally, the benefits and pitfalls of using analogical reasoning for risk and cost overrun assessment of construction projects are discussed.

Keywords: Artificial Intelligence, Case-Based Reasoning, Cost Increase, Risk Assessment, Vulnerability

ÖZ

İNŞAAT PROJELERİNDE RİSKLERİN VE MALİYET ARTIŞININ ANALOJİ KURMA YÖNTEMİYLE TAHMİN EDİLMESİ

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Proje maliyet artışı, uluslararası inşaat projelerinin en büyük sorunu olmakta ve genellikle proje tarafları arasında anlaşmazlıklara ve uyuşmazlıklara sebep olmaktadır. Bu tezin amacı uluslararası inşaat projelerinde geçmiş risk olaylarını temsil eden bir veritabanı oluşturmak ve bir maliyet artışı kestirim modeli kurmaktır. Proje, şirket ve ülke ile ilgili risk faktörlerinin büyüklüklerinin, risk kırılganlığının seviyesini diğer projeler ile benzerlik kurup değerlendirerek kestirimde bulunulabileceği hipotezinde bulunulmuştur. Kırılganlık ve risk faktörleri uluslararası inşaat projelerinin ihale hazırlık aşamalarında da maliyet artışı kestiriminde kullanılabilmektedir. Böylece, 66 tanesi gerçek, 100 tanesi varsayımsal olmak üzere 166 tane uluslararası inşaat projesi verileri kullanılarak risk kırılganlıklarını risk faktörleri ve maliyet ile bağlayan kestirim modelleri hazırlanmıştır. Kestirim modelleri, vaka-tabanlı çözümleme (VTÇ) tekniği kullanılarak oluşturulmuştur. Değişik ağırlıklar yaratılıp, erişim yöntemleri kullanılarak çeşitli VTÇ modellerinin performansları denenmiş, ve proje maliyet artışları +/- 7.15% oranında bir hata ile hesaplanabilmiştir. VTÇ modellerinin, potansiyel risk faktörleri kaynakları ve maliyet artışının kestiriminde kullanımı, gerçek proje çalışmalarıyla gösterilmiştir. Son olarak, inşaat projelerinde risk ve maliyet artışı değerlendirmelerinin benzerlik kurularak yapılmasının kuvvetli ve zayıf noktaları belirtilmiştir.

Anahtar Kelimeler: Yapay Zeka, Vaka-Tabanlı Çözümleme, Maliyet Artışı, Risk, Risk Kırılganlığı

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Dedicating to my family…

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LIST OF ABBREVIATIONS

AC	Adverse Change
AI	Artificial Intelligence
ANN	Artificial Neural Networks
BOT	Build-Operate-Transfer
CBR	Case-Base Reasoning
DB	Design-Build
DBB	Design-Bid-Build
DBOM	Design-Build-Operate-Maintain
FIDIC	Fédération Internationale des Ingénieurs-Conseils
PM	Prediction Model
PRM	Project Risk Management
RBR	Rule-Base Reasoning
RC	Risk Consequence
RE	Risk Event
RS	Risk Source
V1	Vulnerability Group 1 (robustness)
V2	Vulnerability Group 2 (manageability)
V3	Vulnerability Group 3 (resilience)

CHAPTER 1

INTRODUCTION

In international constructions, project cost increase is one of the main concerns which can cause disputes and conflicts among the project participants (owner of the project, contractors, subcontractors, engineer and partners). Unfortunately, the increase in the cost cannot be shared among the project participants without objections and leads to international arbitration. The participants may end up wasting a lot of time and money and reputation loss after all these series of events.

This thesis is a part of ongoing research carried out at the Middle East Technical University which aims to develop a multi-agent platform that simulates the risk and cost overrun allocation between project participants in international projects. The objective of this thesis is to develop a cost overrun prediction model which will act as an independent agent in the platform. The predictions are based on the concepts of risk, risk management and vulnerability which are briefly explained below.

Risk is a measurable uncertainty which is originated from an unforeseen future and vagueness in context (Dikmen *et al.*, 2007). In construction business, risk may be defined as the probability to be exposed to occurrences of events which may adversely affect project objectives as a consequence of uncertainty. Actually, the risk outcomes could have a negative or a positive effect, but, risk studies usually concentrate on the negative ones.

Project risk management (PRM) process is composed of three main parts. First one is *risk identification* where sources of uncertainty are identified, the relevant risk factors are distinguished and documented. Second part is *risk analysis* in which consequences of uncertainties are estimated by determining their magnitudes and considering their impact on the project. The third one is *risk handling/response development* part in which response strategies are generated to reduce the likelihood of occurrence of risk events and/or to lower the negative impact of those risks to an acceptable level.

The term *vulnerability* is generally used to indicate the degree to which a project is susceptible to adverse effects. It exists within systems (independent of external hazards) and depends on the organization's capability to manage risks (along with other social and economic factors). The term vulnerability in this thesis is the same as that defined by Fidan (2008), and is used to describe all factors that make the system more susceptible to damage in case of a risk occurrence, and risk consequence is accepted as a function of risk event and vulnerability.

Dikmen *et al.* (2007) defined the influence of a system as a "controllability/ manageability issue". In their study, they mention the fact that probabilistic relationships between risk events and consequences are not enough to describe the project risks as they fail to capture the influence of project systems. The actual consequences of risk events depend on an organization's capability to manage risks, thus, the company factors as well as the project characteristics that affect project vulnerability should be taken into account as shown in Figure 1.1. Although they emphasize the importance of system influence on risk consequences, they do not give any detail about how to integrate vulnerabilities with risk consequences; moreover they do not present a detailed list of vulnerability parameters.

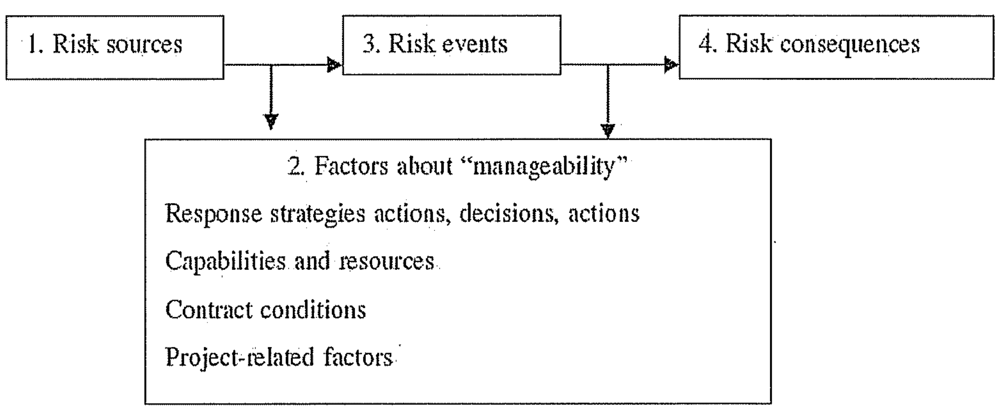

Figure 1.1 Risk information model (developed by Dikmen, 2007).

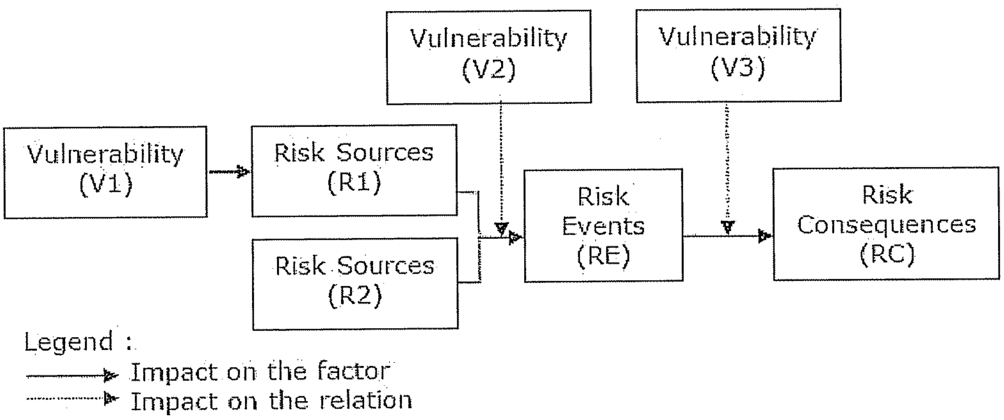

Figure 1.2 Risk-vulnerability model (developed by Fidan, 2008).

Fidan (2008) extends Dikmen's model by constructing a generic structure that encompasses the risk-vulnerability paths once the risk and vulnerability parameters are determined, as shown in Figure 1.2. In that study, the collected vulnerability factors are categorized according to their influences on risk paths where some factors affect the probability of occurrence of risks whereas others affect only the relations between risk sources, events and consequences.

Vulnerability factors may affect the level of risk in three different ways:

- Vulnerability (V1), *robustness*, refers to the factors that affect the probability of occurrence of risk. Robustness factors are grouped under four main categories: country, project, parties and company.
- Vulnerability (V2), *resilience*, refers to the factors that affect manageability of risk. Resilience factors contain the issues related with contractor such as the experience, resources and managerial capability of the company.
- Vulnerability (V3), *sensitivity*, refers to the factors that influence the magnitude of impact of risk events on project success. Sensitivity factors contain several project related parameters such as project delivery system, payment type, etc.

Fidan (2008) categorizes the risk items by questioning whether an item has potential to cause problem (*risk source*), or it is itself a problem (*risk event*), or it is the actual consequence of a negative effect (*risk consequence*).

- The *risk sources* (RS) are divided into two groups: adverse change and unexpected event. Adverse change implies a negative variation from the initial conditions of the project whereas unexpected events happen suddenly and cause problems in a project, such as force majeure events and accidents.
- The *risk events* (RE) are related with variations on productivity, quantity of work, relations etc.
- The *risk consequence* (RC) is defined based on the assumption that there are two project success criteria: cost and schedule. In the present thesis, project cost increase is taken as the only project success criterion.

In this thesis, the model of Fidan (2008) is accepted as the structure of the ontology and her terminology is also used for vulnerability, robustness, sensitivity, resilience, risk source, risk event and risk consequences.

International construction projects have many influencing factors which are usually hard to quantify, and the magnitudes of these factors are subjective. This makes it difficult to specify generic rules valid for all projects. In order to handle this complexity, many researchers proposed using artificial intelligence (AI) techniques to predict project cost increases, and a detailed research on figuring out which artificial intelligence technique gives better results is made as well. Literature survey on the artificial intelligence models is given in Chapter 2.

This research aims to identify project-related, company-related and country-related risk factors and to predict the cost increases at the bid preparation stages of projects. Within the context of this research, a database is constructed which can be used in the forthcoming projects for forecasting the cost overrun and sharing the possible cost increase among project participants. This database and information system can be useful for Turkish contractors in international construction projects by helping them to make realistic estimates beforehand and reduce their financial and reputation loss.

A survey, given in the Appendix - A, is prepared to collect information about previous projects. It is composed of three parts. In the first part, general information about the company and project is gathered. In the second part, questions are asked related with the factors that may potentially create risk in international construction projects. Determining importance weight for each factor (from the contractor's general point of view) is the aim of the second part. In the third part, project-specific information and the cost increase is gathered.

In the survey, all questions which might lead to identification of the company are excluded, and all information that a firm gives is treated as confidential. Project and firm names are not gathered, and no comment is made on any project-specific information which might lead to identification of the participant companies. Detailed information about the surveys conducted and lists of the parameters are explained in Chapter 3.

With the help of the present survey, alternative models are proposed and tested to find the best one that gives the most accurate results in predicting the project cost increase. After figuring out which artificial intelligence technique is appropriate (in Chapter 2), the results of initial findings are given in Chapter 4.

In this study, additional hypothetical projects are created with the help of experts in this field to increase the reliability of the models. Advantages of using hypothetical cases and detailed information on how they are created are given in Chapter 5.

With the help of additional hypothetical projects, models are put to use again to predict the project cost increases for international construction projects. Final result for each model with the reliability rates are given in Chapter 6.

A Java program has been written in order to make the software program used in the present research more user friendly. Detailed information on how the Java program is used and advantages are given in Chapter 7.

Finally, conclusions for this research and recommendations for the future researchers are given in Chapter 8.

In the appendices, the surveys used for gathering information about international construction projects are given alongside with the outputs of the software program predicting the project cost increase.

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CHAPTER 2

CASE-BASE REASONING

2.1 What is Case-Base Reasoning?

Broadly speaking, case-base reasoning (CBR) is a computational technique used in making predictions for the solutions of a current problems by employing past experience of similar problems and by using information and knowledge of those situations. To explain what CBR is with an example, one may consider the case in which a physician determines the disease and treatment for a new patient by using the diagnosis and treatment of previous patients if the important symptoms are similar. [Aamodth and Plaza (1994)]

Chen and Burrell (2001) state that "*the CBR approach focuses on how to exploit human experience, instead of rules, in problem solving and thus improves the performance of decision support systems*".

Also, according to Li (1996) "*CBR is applicable to solve problems and make decisions when cases are available but the knowledge needed is so vague that formatting decision rules is infeasible. A Case-Base Reasoning (CBR) system consists of a case base and a reasoner, where the case base contains the problem solving experiences as cases, and a reasoning mechanism uses the case base to derive solution from the cases. If the problem encountered is exactly the same as the problem being solved previously, then it is considered as a solved case, and the previously stored solution is applied to the current problem without any modification. If the problem is not exactly the same as any of the stored cases, then a similar case is chosen to be modified in order to meet the* *needs of the problem request. This process consists of looking up the case base for a similar case and adapting the case to meet the requirements of the problem*".

Rich and Knight (1991) argue that a successful CBR system must answer the following questions:

- How are cases organized in memory?
- How are relevant cases retrieved from memory?
- How can previous cases be adapted to new problem?
- How are cases originally acquired?

Finally, it is also worth paying attention to the explanation given by Aamodth and Plaza (1994): "*Case-based reasoning is a problem solving paradigm that in many respects is fundamentally different from other major AI approaches. Instead of relying solely on general knowledge of a problem domain, or making associations along generalized relationships between problem descriptors and conclusions, CBR is able to utilize the specific knowledge of previously experienced, concrete problem situations (cases). A new problem is solved by finding a similar past case, and reusing it in the new problem situation. A second important difference is that CBR also is an approach to incremental, sustained learning, since a new experience is retained each time a problem has been solved, making it immediately available for future problems*".

2.2 Working Principle for Case-Base Reasoning

Working principles of CBR is illustrated by Lee *et al.* (2005), use Figure 2.1. Consider a service request (*new problem*) from the user. Then, the case base (*historical usage*) is looked up (which stores the previous cases) to check similarity with the *old problems* and the most similar case is retrieved in order to use the information on the previous service as the solution (*old solution*) to the service request. If only a close case is found, then the solution (*new solution*) is tailored for the request. In other words, after looking up solutions of old problems, new solution is adapted according to the similarity rate. It should be noted that by 'service' what we mean here is not only the Web services but also all of the actions to satisfy the user request or intention.

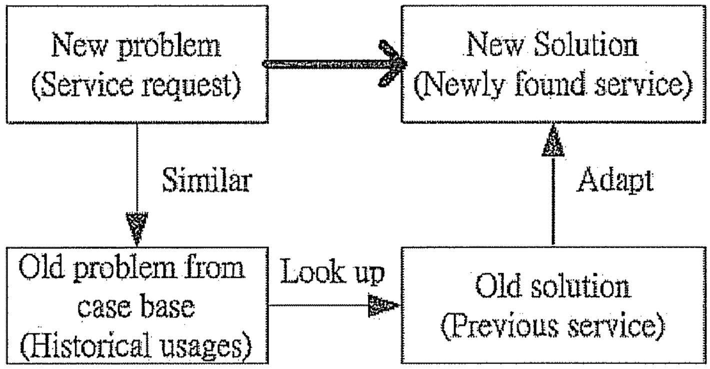


Figure 2.1 Principle of CBR (according to Lee *et al.*, 2005).

Chua *et al.* (2001) use the same principle however in slightly different way. According to them, CBR comprises essentially three tasks:

1. retrieves one or small set of the most similar cases,
2. solves the new situation by reusing or revising former solutions,
3. retains the new case and solution as part of past cases for future retrievals.

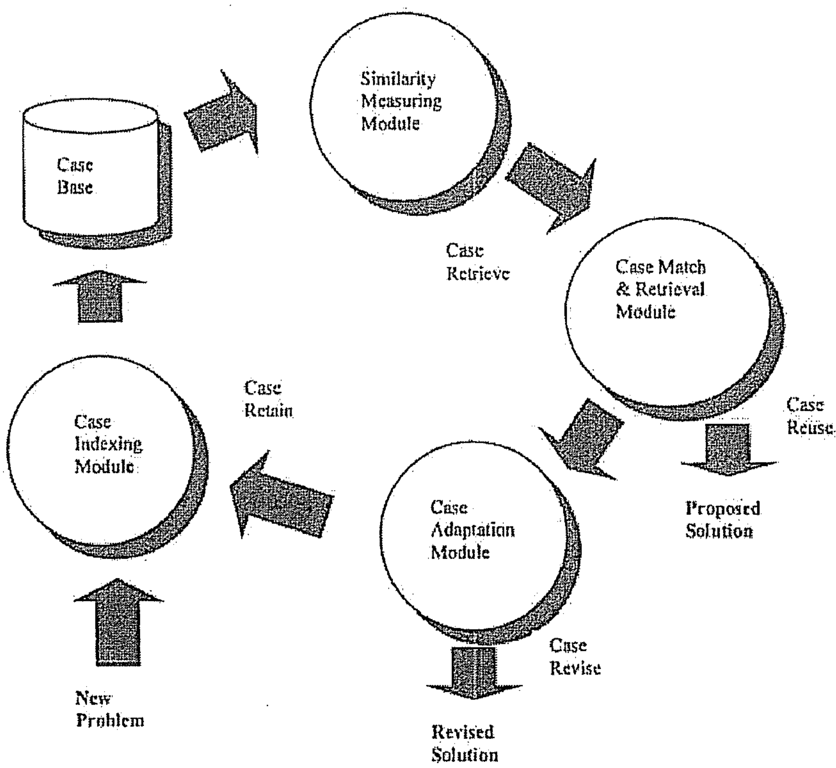


Figure 2.2 Principle of CBR (according to Chua *et al.*, 2001).

A CBR system typically consists of a case library, which is a repository of past cases, and several interrelated components or modules to achieve the three tasks mentioned above, as shown in Figure 2.2. The case indexing module allows a case to be uniquely represented, indexed, and partitioned in the case library. The similarity measuring module computes the similarity between the new case and the cases in the case library. The case match and retrieval module ensures that the cases with higher similarity value are retrieved when required. Solutions of the similar cases can be used as inspiration for solving the new problem. Since a new situation rarely matches old ones exactly, old solutions must be adjusted to fit the new case. The case adaptation module performs the reasoning over the most similar case or a set of similar cases retrieved and carries out the necessary data analysis to adapt the case(s) for a proper solution.

According to Aamodth and Plaza (1994), a CBR cycle may be described by the following four processes:

1. RETRIEVE the most similar cases,
2. REUSE the information in that case to form a solution,
3. REVISE the solution,
4. RETAIN the new experience by incorporating it into the existing knowledge-base (case-base) for the solution of future problems.

This is illustrated in Fig. 2.3. When a new problem is given, first similar cases are RETRIEVED from the previously stored cases. The retrieved cases are combined with the new case - through REUSE - to form a proposed solution. This solution is tested (usually by applying to the real world) through the REVISE process and modified if necessary. The new experience is RETAINED for future use, and the case base is updated.

These concepts are also used in this thesis, and brief information about the above four processes are given in the following section.

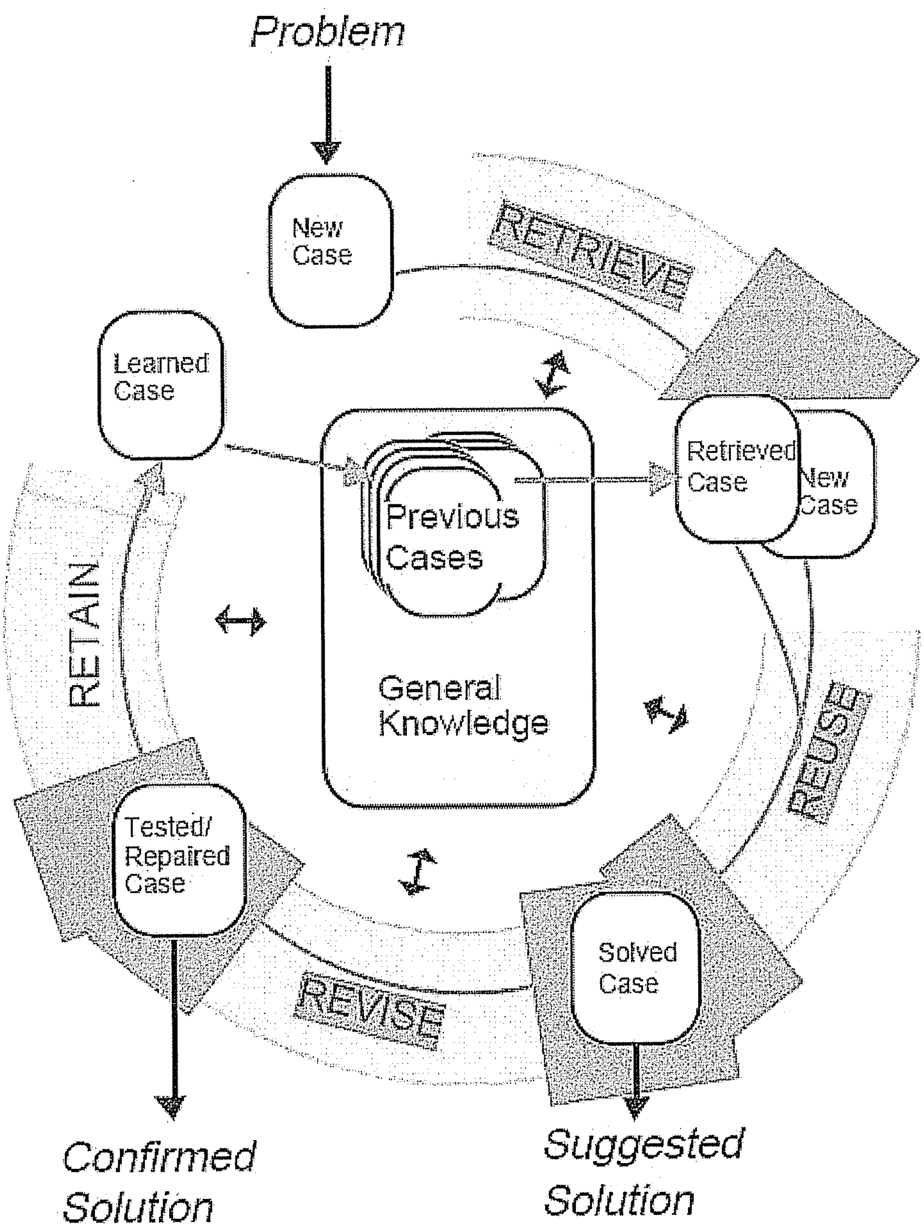


Figure 2.3 Principle of CBR (according to Aamodth *et al*, 1994).

2.2.1 Retrieval of the Cases

Case retrieval phase starts with the identification of the cases stored in the system's database and end with the case matching procedure. In order to retrieve cases from case libraries, identification of important features are needed. After features are listed, importance weights for each feature need to be determined. This is a crucial step in order to find the similarity ratings in the next phase.

2.2.2 Case Reuse

The major aspect of the case reuse is to find the differences between the new and the old cases. Using the available importance weights, similarity rules are applied to determine the similarity rate between the new case and the previous cases (saved in the systems database with the importance features determined earlier). Then, previous cases with high similarity ratings are reused to predict the possibility of the outcome of the new project which is done in the case revision phase.

2.2.3 Case Revision

Case revision has two tasks: (a) to evaluate the prediction method generated in the case-reuse phase and (b) to come up with a solution. Using the similarity and prediction rules (figured out in case reuse), evaluation is done in case revision and solution may be used either directly or after some "repair" (by adjusting the prediction and similarity rules) to find a better result.

2.2.4 Case Retaining

This phase is probably what makes the CBR so important. This "learning" process, saves the new case into the case library, and allows the user to use it at the retrieval phase when a future case is tested. This phase allows the CBR to enhance itself and improve the evaluation with each additional case saved in its database.

Detailed information and examples for each step are given in the following chapters.

2.3 Use of Case-Base Reasoning outside Construction Field

The first system that might be called a case-based reasoner was the CYRUS system, developed by J. Kolodner (1983), at Yale University. It was basically a question-answering system with knowledge of the various travels and meetings of the former US Secretary of State Cyrus Vance. The case memory model developed for this system has later served as the basis for several other case-based reasoning systems such as MEDIATOR (Simpson, 1985), PERSUADER (Sycara, 1988), CHEF (Hammond, 1989), JULIA (Hinrichs, 1992) and CASEY (Koton, 1989).

Use of CBR is widely expanded after its knowledge and principle have been accepted. CLAVIER (Hennessy, 1992) is the first CBR program that engineers have used in engineering. This program built up similarities between the new and old problems, created new solutions, and hence, had a huge impact on forthcoming projects. With CLAVIER, engineers started to use case-base reasoning in their own sectors.

After Sycara first built PERSUADER, she then joined up with Miyashita to build a case-based schedule repair program called CABINS (Sycara, 1994). In CABINS, case-based reasoning is used for eliciting situation-dependent user's tradeoffs about repair actions and schedule quality to guide schedule revision and improve quality.

Roddis and Bocox (1997) built the CB-BFX program to use case-based reasoning concept to provide an accurate, efficient and reliable mechanism for solving steel bridge fabrication error.

The use of case-base reasoning outside the construction management is not limited with the list given above and can expand further.

2.4 Use of Case-Base Reasoning in Construction Field

Nowadays, case-base reasoning application is used in almost all branches of the construction sector. Going chronologically, Deng (1994) used case-based reasoning as a decision support tool. In his work, he proposed a computational case-based reasoning model, and investigated its feasibility to decision support.

Thomas Ng (2001) built EQUAL which is a case-based contractor pre-qualifier developed to capture and reuse knowledge based on experience. It helps to produce more reliable and expeditious decisions for contractor pre-qualifications.

Chua *et al.* (2001) use case-based reasoning in decision making as well, and have built a case-based reasoning bidding system, CASEBID, that helps contractors with the dynamic information (varying with the specific features of the job and the new situation). The CASEBID program approaches the bidding problem by assessing the level of competition and risk from the past similar cases to arrive at optimal markup.

Case-base reasoning has been used in procurement stage as well. Luu *et al.* (2005) adapts CaPS program in order to retrieve previous problems occurred in procurement selection, and allows the users to adapt the solution through null adaptation or critic-based adaptation to new cases.

CBR-INT developed by Ozorhon *et al.* (2006) is constructed to demonstrate how experiences of competitors in international markets may be used by contractors and to support international market selection decisions. They state that CBR-INT can be used for predicting potential profitability of international projects and the level of competitiveness of Turkish contractors.

After CASEBID, Chua continued to use case-based reasoning approach in contract strategy formulation and built CB-Contract (Chua, 2006) with the objective to provide systematic support for strategy formulation and systematic retention of knowledge.

Dikmen *et al.* (2007) has come up with a case-based program for bid mark-up estimation of international construction projects. A case-based reasoning model has been developed to estimate risk, opportunity and competition ratings to determine risk and profit mark-ups considering worst, average and best scenarios.

Naderpajouh *et al.* (2008) use case-based reasoning approach in value engineering methodology. A workshop is organized to test the CBR model and it is shown that the created model could contribute significantly to the efficiency of the value engineers, providing an extensive memory of past experience (saved in the case library).

Chen *et al.* (2008) have built a case-base reasoning program that involves onsite supervisory manpower in construction projects. They claim that the CBR program has a high rate of accuracy (88.5 %) for predicting onsite supervisory costs and allocations.

CBR approaches have also been applied to various other construction related domains, including architecture design (Schmitt, 1993), construction negotiation (Li, 1996), design, planning, scheduling, cost estimation (Perera *et al.*, 1998; Yau *et al.*, 1998; Tah *et al.*, 1999; Dzeng *et al.*, 1997) and construction litigation (Arditi *et al.*, 1999).

2.5 Justification for Choosing Case-Base Reasoning

In construction management, three main artificial intelligence techniques are generally used. The techniques for developing knowledge-based systems are rule-based reasoning (RBR), case-based reasoning and artificial neural networks (ANN). In this study, the case-base reasoning technique has been chosen to create a model to predict the project cost increase and the justification for that is explained below.

Rule-based reasoning systems are the traditional systems and are also called expert systems. They are based on rules and their applicability is limited, as it is almost impossible to define generic rules for the dynamic project conditions. The drawbacks related with RBR may be listed as: difficulties of knowledge acquisition, no memory of tackled problems or previous experience, poor efficiency of inference, ineffectiveness to deal with exceptions and poor performance of the whole system. However, CBR can handle the above problems well because it is based on cases and is easier to acquire than to obtain rules and can reuse past results. It does not need mental analysis for every step starting from the very beginning, and improves efficiency when solving a new situation. Consequently, it offers more power and control than does RBR.

There are also the ANN-based models but the user has less control over it. Their reasoning process is concealed from the decision-maker and they have black-box computations. Liu and Ling (2005) use a fuzzy neural network technique which uses fuzzy inference rules rather than a hidden layer. They claim that results of their model are more traceable but still it is very hard to derive generic rules for complex situations.

A CBR system draws its knowledge from a reasonably large set of cases contained in the case library of past problems rather than from a set of rules only. It solves new problems by adapting solutions that are used in solving old problems. Its reasoning process is much easier to understand for the user when compared to ANN models. CBR mimics how humans reason and is based on experience that may not be necessarily transformed into rules. One of the main advantages of this problem-solving approach is that its reasoning process can easily be followed and it is strengthened by the possible human intervention at several steps, unlike in the case of ANN-based models.

Some information related with the construction sector is qualitative rather than quantitative. When dealing with qualitative items, usage of case-base reasoning provides benefit over ANN because it cannot take any qualitative information (converts all its input data into numerical, 0/1, values). During this conversion, links to qualitative values may be broken or at least adversely affected to some degree. Moreover, this conversion inevitably increases the number of parameters to define the projects, and therefore increases the chance to make mistakes.

The main principle of ANN is to bond the sources that create the problems (vulnerabilities) with the consequences (increase in project cost). Therefore, if ANN is used, the bond between the vulnerabilities and consequences should be checked in detail to see whether the bond is logical or not. Even when minor adjustments are made or whenever a new project is added to the system's database, the links need to be tested all over again. CBR's ability to enhance itself automatically offers convenience.

Another advantage of CBR is that it can show the reasoning behind the consequence through the help of the similarity scores. On the other hand, ANN acts like a black box and does not show detailed information on how the solution is determined through the vulnerabilities. Also, CBR gives importance weights for each feature defined for construction projects. After the importance weights are determined, they are not changed when a new project is saved into system's database. Therefore, there is no need to test the entire system all over again each time a new project is included, and testing phase for CBR becomes a lot less than that for ANN.

When ANN is used, the hidden information has a high chance to lead to false conclusions. However, in CBR, the system is not affected as much due to the fact that it works with similarity ratings. If the amount of screened information is too much about a project, then CBR simply does not make a conclusion, whereas ANN has a high probability of creating false links and wrong conclusions.

When cost increase is considered in international construction projects, the compound effects of a number of parameters (interrelated with the country, market and project levels) should be considered together. But, it is very hard to derive a formula that maps all these input parameters, and in practice, intuition and gut feelings are typically used to handle this problem. Consequently, AI techniques such as ANN and RBR cannot fully reflect lessons learned from previous projects and the conceptual models that resides in the heads of experienced decision makers. On the other hand, CBR applies human reasoning when examining cases, uses past experiences to make decisions about future events, and hence, is more powerful.

Another important issue for the long-term use of these models is that they should be updated with new cases after they are designed. In the ANN system, this is difficult because the system needs to be retrained whenever new cases are added. This is a long process because each parameter and algorithm used is tested again, and the results are expected to change because of each addition. On the other hand, in CBR the only change needed is a new weight generation method to update the new information. This takes much less time than the exhaustive training runs that an analyst has to conduct with an ANN system.

For the reasons mentioned above case-base reasoning is used in this study. Questionnaire (in Appendix -A) is used to gather information regarding international construction projects and models are created to predict the project cost increases. Details regarding the models and questionnaire are given in the forthcoming chapters.

CHAPTER 3

RESEARCH METHODOLOGY AND DATA COLLECTION PROCESS

3.1 Data Collection

To be able to use a case-base reasoning program with confidence, large amount of data need to be collected. In the present study, surveys (in English/Turkish, presented in the appendix) have been prepared with the help of contractors who have completed international projects in the past. Also, before the surveys are sent to contractors, a small pilot-demonstration is done with four participants from different Turkish contract companies. The participants are asked to evaluate whether the designed survey parameters are comprehensible or not, whether additional parameters should be included and if any of the parameters are unnecessary or redundant. After the participants check the surveys, necessary adjustments are made and data gathering process is started.

In order to get information from engineers/managers who are currently abroad and working on construction sites, the prepared surveys are placed in the following website (http://www.surveymonkey.com/s.aspx?sm=F0f_2bNnviNKXFQgLhap9BEg_3d_3d). E-mails are sent to these engineers/managers, explaining the whole survey in detail and requesting them to complete the survey for each project they have finished. Unfortunately, response rate to these e-mails and the web survey has been very low. Another deficiency of these surveys is that when the participants come across to a parameter they do not fully understand, they usually do not respond and the interviewer does not have a chance to explain the specific parameter.

In parallel to the surveys conducted by e-mails with the participants who are currently abroad, face-to-face interviews have also been conducted with the employees of Turkish construction companies in Ankara and in Istanbul. These face-to-face interviews have been considerably more efficient due to fact that the questionnaires are explained to the participants more accurately, and questions/feedbacks related with the surveys are received instantly.

The questionnaire is composed of three main parts. In the first part, general information about the company and project is gathered. All questions which might lead to identification of the company are excluded. In the second part, a list of factors that have potential to create risk in international construction projects is given and the participants are asked to determine importance weights these factors. In the last part, information is gathered about the specific projects, and amount of cost increase is asked for each project.

Efforts are spent to make the survey information (about international construction projects) as objective as possible. The risk parameters are evaluated by using a scale from 1 to 5 where 1 stands for very low, 2 is low, 3 is medium, 4 is high and 5 means very high risk rating. It should be noted that in gathering information two types of problems are encountered. First is related to the personality of the participants. Some managers might evaluate a specific project with high risk rating and another manager with normal risk rating depending on whether they are risk averse or risk seeking. In determining the importance weights and potential of these factors to create risks in general terms (second part of the survey) it is assumed that the participants indirectly reflect their own profiles. For example, if a participant gives high ratings in the initial stages, then the ratings he/she gives on later stages will be high as well. Having the same logic, a participant who scores low ratings in the initial questions will have the tendency to continue to score lower rating in the following questions. This is taken into account after finishing the survey.

Secondly, a contractor who has experienced a fatal consequence on a specific risk parameter (*e.g.* partnership problems) might score very high risk ratings to partner related risk factor while underestimating the other major risk probabilities. Therefore, instead of gathering different projects from different employees in the same company, efforts are spent to gather as many projects as possible from each employee. Moreover, in order to prevent survey participants to affect each other, interviews are made with individuals instead of groups.

3.2 Factors Affecting Project Cost Increase

After conducting a thorough research with feedbacks from pilot-demonstration, a total of 122 parameters are selected as factors affecting the unexpected cost increase in international construction projects. These factors are divided into three main groups (namely, firm and project information, vulnerability factors and adverse change factors) as shown in Table 3.1.

Table 3.1 Factors that influence project cost increase

	A. FIRM and PROJECT INFORMATION
A.1	Project type
A.2	Country the project took place
A.3	Year the project started
A.4	Total project cost (original contract value)
A.5	Project duration
A.6	Contract type
A.7	Project delivery system type
A.8	Project payment type
A.9	Company's role in the project
	B.VULNERABILITY (ROBUSTNESS) FACTORS
B.1	Instability of economic conditions
B.2	Instability of government
B.3	Instability of international relations
B.4	Level of bureaucracy
B.5	Level of bribery

Table 3.1 continue

B.6	Level of mafia power
B.7	Instability of social conditions
B.8	Immaturity of legal system
B.9	Restrictions for foreign companies
B.10	Unavailability of material
B.11	Unavailability of equipment
B.12	Unavailability of labor
B.13	Unavailability of subcontractor
B.14	Unavailability of infrastructure
B.15	Complexity of design
B.16	Incomplete design
B.17	Low constructability
B.18	Design errors
B.19	Complexity of construction method
B.20	Poor accessibility of site
B.21	Inadequate geotechnical investigation
B.22	Inadequate climate conditions
B.23	Strict quality management requirements
B.24	Strict environmental management requirements
B.25	Strict health & safety management requirements
B.26	Strict project management requirements
B.27	Vagueness of contract clauses
B.28	Contract errors
B.29	Partner's technical incompetence
B.30	Partner's managerial incompetence
B.31	Partner's lack of financial resources
B.32	Partner's cultural differences with the company/contractor
B.33	Designer's technical incompetence
B.34	Designer's managerial incompetence
B.35	Designer's lack of financial resources

Table 3.1 continue

B.36	Designer's cultural differences with the company/contractor
B.37	Consultant's technical incompetence
B.38	Consultant's managerial incompetence
B.39	Consultant's lack of financial resources
B.40	Consultant's cultural differences with the company/contractor
B.41	Client's lack of clarity of objectives
B.42	Client's level of bureaucracy
B.43	Client's negative attitude
B.44	Client's poor staff profile
B.45	Client's unavailability of financial resources
B.46	Client's technical incompetence
B.47	Client's poor managerial/organizational ability
B.48	Company's lack of experience in similar projects
B.49	Company's lack of experience in country
B.50	Company's lack of experience in project delivery system
B.51	Company's lack of experience with client
B.52	Company's lack of experience with partner
B.53	Company's lack of financial resources
B.54	Company's lack of technical resources
B.55	Company's lack of staff
B.56	Company's lack of project scope management
B.57	Company's lack of project time management
B.58	Company's lack of project cost management
B.59	Company's lack of project quality management
B.60	Company's lack of project human resource management
B.61	Company's lack of project communications management
B.62	Company's lack of project risk management
B.63	Company's lack of project procurement management
	C. RISK SOURCES/EVENTS and CONSEQUENCES
C.1	Currency rates

Table 3.1 continue

C.2	Inflation
C.3	Tax rates
C.4	Laws and regulations
C.5	Relations with the government
C.6	Relations with the partner
C.7	Relations with the consultant
C.8	Relations with the designer
C.9	Relations with the client
C.10	Communication between parties
C.11	Performance of the partner
C.12	Performance of the designer
C.13	Performance of the engineer
C.14	Scope
C.15	Design
C.16	Construction technology/method
C.17	Client's staff
C.18	Original schedule/sequence
C.19	Site organization
C.20	Project team (project manager, technical office members)
C.21	Top management (company)
C.22	Availability of labor
C.23	Availability of material
C.24	Availability of equipment
C.25	Availability of subcontractor
C.26	Public reaction
C.27	Attitude of client
C.28	Geological conditions
C.29	Site conditions
C.30	Financial situation of the client
C.31	Financial situation of company

Table 3.1 continue

C.32	Financial situation of the partner
C.33	Performance of contractor
C.34	Social unrest/disorder
C.35	War/hostilities
C.36	Rebellion/terrorism
C.37	Natural catastrophes
C.38	Historical findings
C.39	Accidents
C.40	Damage to equipments
C.41	Theft
C.42	Strikes/labor problems
C.43	Decrease in productivity
C.44	Increase in quantity of work
C.45	Decrease in quality of work
C.46	Increase in unit cost of resources
C.47	Delay in bureaucracy
C.48	Delay in site hand-over
C.49	Delay in logistics
C.50	Delay in progress payments

In the first part (firm and project information), some general information related to the project is asked considering the fact that participants would like to evade any answers that might be confidential for their respective companies. Three of the questions require numerical answers, namely, the year project started, total project cost and project duration. Also, the country where the project took place is the only question that the participant answers in writing. All other parameters are simply checked from a list by the participants.

In the second part, the magnitude of the vulnerability factors are asked (project specifically). The aim is to link the effects of the vulnerability factors to adverse changed parameters through the project which affect the unexpected cost increase.

In the third part, information is obtained related to the adverse change factor parameters that affect the cost increase directly.

3.3 Overview of How the Factors Affect Project Cost Increase

3.3.1 Firm and Project Information

3.3.1.1 Project Type

The factors that may affect cost increase vary greatly depending on the type of the project. For example, coastal structures are affected more from external factors, whereas pipelines and infrastructures are more affected by geotechnical factors. Complex projects such as industrial plants, dams, energy related buildings (*e.g.* nuclear, hydroelectric plants) are more prone to being affected than simple housing or regular building (shopping malls etc.) structures. Also, design, construction technique, geotechnical and other requirements are directly related with the project type. Therefore, categorizing the project according to its type is very important in initial stages.

3.3.1.2 Country the Project Took Place

The country where the project take place has direct impact on the vulnerability parameters as well. Certain countries (such as most European countries) have more paperwork and thus more bureaucratic factors. As an example, management requirements such as health and safety regulations can be more decisive than the other parameters. On the other hand, some other countries might have problems related with political instabilities, unavailability of market conditions, bribery and mafia power.

3.3.1.3 Year the Project Started

It is important to note when the project is started. A country's economic, political, social, legal and marketing conditions may change dramatically over the years, and depending on the year of the project availability of certain materials (such as steel) can be very different. For example, the present construction conditions in Türkiye are very different from those 20 years ago, and will probably be much more different in another 20 years.

3.3.1.4 Total Project Cost (Original Contract Value)

Total project cost is another parameter one has to take into consideration in the initial stages. First of all, company's resources are directly challenged by the budget of the project. The company's vulnerability and managerial abilities are affected by the size of the specific project's budget. Secondly, effects of any changes in the design or scope of the project are closely related with total project cost. If the project is small, then a few changes in the design or scope might not make much effect on the overall cost. But, as the project cost increases, every little change might have a huge impact on the overall cost due to the snowball effect and millions of dollars might be at stake.

3.3.1.5 Project Duration

Duration of a project is the time between the start and completion of a project. Contractors prefer to shorten the project duration, because project cost and vulnerability of the project to unexpected events increases with it.

3.3.1.6 Contract Type

The type of contracts directly affects the vulnerability parameters in international construction projects. FIDIC (Fédération Internationale des Ingénieurs-Conseils) is the most common type, and is best known for its range of standard conditions of contract for construction, plan and design-build, turnkey projects and design-build-and-operate projects. However, although some projects are undertaken as international projects, if the project is a public one, the host country might force to use the local regulations as the contract type. Depending on the situation, company can lure the host country to conjoin FIDIC and local regulation together and a project-specific contract may be used, as well. Obviously, depending on the unforeseen adverse conditions, the type of the contract may have a big influence on the unexpected project cost increase.

3.3.1.7 Project Delivery System Type

A project delivery method is a system used by an agency or owner for organizing and financing design, construction, operations and maintenance services for a structure or facility by entering into legal agreements with one or more entities or parties. Common project delivery methods include Design-Bid-Build (DBB), Design-Build (DB), Design-Build-Operate-Maintain (DBOM) and Build-Operate-Transfer (BOT). In DBB, an owner develops contract documents with an architect or engineer consisting of a set of blueprints and detailed specifications. Bids are solicited from contractors based on these documents; a contract is then awarded to the lowest responsive and responsible bidder. From time to time, with partially completed contract documents, an owner will hire a construction manager to act as an agent. As substantial portions of the documents are completed, the construction manager will solicit bids from suitable subcontractors. This allows construction to proceed more quickly and allows the owner to share some of the risk inherent in the project with the construction manager. As for DB, an owner develops a conceptual plan for a project, and then solicits bids from joint ventures of architects and/or engineer and builders for the design and construction of the project. DBOM takes DB one step further by including the operations and maintenance of the completed project in the same original contract. BOT represents complete integration of the project delivery: the same contract governs the design, construction, operations, maintenance and financing of the project. After some concessionary period, the facility is transferred back to the owner. Depending on which project delivery system type is used, vulnerability parameters related with project and project participants (owner, partner, designer, subcontractors etc.) can have direct impact on the unexpected project cost increase when things do not go as planned.

3.3.1.8 Project Payment Type

Project payment type, which can be categorized into unit price, lump sum, and cost-plus-fee, may have direct impact on the unexpected project costs increase.

When the cost-plus-fee method is used to determine the contract sum, the contractor is reimbursed for the actual cost of labor and materials and is paid a fee for overhead and profit (the fee may be a percentage of the labor and materials costs or a fixed amount). With this method, the contract sum is not fully determined until the work is completed (the initial contract sum is the amount of the fixed fee or the percentage due to contractor which will be converted to a dollar amount after completion of the work). Cost-plus-fee is the most desirable project payment type for construction companies due to the fact that construction companies secure their profit even in the worst cases. No matter which unexpected event may occur, contractor will simply specify the costs that the company has paid and will claim the cost plus the additional fee percentage that was agreed with the client previously. Usual practice is that cost-plus-fee type contracts are performed on the basis of direct negotiation between contractor and the client without a formal tender procedure, and this allows a lot of incentive to the contractor. However, cost-plus-fee payment type is usually not desirable for clients and is not used in international construction projects as much as lump sum and cost-plus-fee.

For some projects, the extent of work cannot be fully determined, or the actual quantities of required items cannot be accurately calculated in advance. In these cases, bidders are requested to submit bids based on unit prices. Unit-price contracts subdivide the work or parts of the work into like items and state approximate quantities for each item. The bidders use these quantities in preparing their bids. A price per unit of measurement (unit price) is quoted for each item. Sums for the extended unit prices are not included in the initial contract sum. As the work is completed, actual quantities are measured, and the contractor is paid according to the contractor's quoted unit prices. Unit price contract type gives more incentive to the owner (client) of the project than cost-plus-fee type therefore it is more accepted in international construction projects.

The most common and simplest method of determining the contract sum is the lump sum method, in which a single amount is quoted for all of the work. The contractor is paid the contract sum in one or more installments. With the lump sum method, the initial contract sum is determined during bidding. Using this method, if the amount bid is within the budget, project is regarded as a successful project; if the amount bid is less than the actual budget, contractor would have to pay the additional costs from its own. Therefore, in general, companies that use lump sum type contracts are carrying almost the entire risk on their shoulders. This is the main reason why owner (client) of the project favors more to lump sum contract types than unit price and cost-plus-fee. Obviously, the type of payment in the construction project is closely related with the company's experience, financial resources and willingness to take this project, and has direct impact on the unexpected cost increase when things go wrong.

3.3.1.9 Company's Role in the Project

Vulnerability factors are closely related to the role of the company in a project, *i.e.* whether it is the sole contractor, a subcontractor, or a partner in a joint venture or consortium. Working as the sole contractor, company takes all the risks in the project. All the construction, gains and losses are in the hands of the company. In joint venture, an entity is formed between two or more parties to undertake economic activity together. Parties agree to create a new entity by contributing equity, and share in the revenues, expenses, and control of the construction. Reasons for forming a joint venture could be spreading costs and risks, improving access to financial resources, economies of scale and advantages of size, creation of stronger competitive units and transfer of technologies between parties. Consortium is an association of two or more individuals, companies with the objective of participating in a common activity or pooling their resources for completing the construction (common goal). In consortium every party is responsible on its own duty and the profits and losses are not divided to companies as it is in joint venture. Lastly, a subcontractor works only in a small portion of the whole construction project being responsible for its own part only. Company's role in the project definitely affects the magnitude of the vulnerability factors, and thus, the unexpected project cost increase in construction projects.

3.3.2 Vulnerability Factors

3.3.2.1 Instability of Economic Conditions

Economic conditions in the host country where the international construction take place can have an impact on the project. It can affect the country's market conditions as well as currency rates and inflation. These can have dramatic effects which can lead to huge money losses if there is no related clause in the contract.

3.3.2.2 Instability of Government

Having an unstable government in the host country could have adverse effects on the bureaucracy, political conditions and an attitude change towards foreign companies. Moreover, if the government has a negative attitude towards imported goods, the market conditions within the host country may change possibly increasing the overall expenses. Bribery, mafia power and other negative factors could be stimulated by the instability of the government.

3.3.2.3 Instability of International Relations

An unstable relationship between the host country and the company's home country could have a massive impact on the project as well. Delays in the customs and in the paperwork of imported goods from different countries, visa problems, negative attitude towards the company, bureaucratic difficulties and other problems can cause the project to stall which could result in project cost increase.

3.3.2.4 Level of Bureaucracy

Paperwork overload, too many manageability requirements, delays in the delivery of materials to the construction site and late payments can have drastic effects on the project. Also, other effects caused by bureaucracy, such as delays in the site hand-over, could increase the duration of project as well.

3.3.2.5 Level of Bribery

Bribery reflects moral outrage at someone, procuring an advantage by paying for it. Researches show that bribery comes second in the most frequent unethical conducts by construction players. Bribery not only costs additional expenses to the construction projects, but also can cause legal problems within the host country producing detrimental effects on the project.

3.3.2.6 Level of Mafia Power

Mafia is a loose association of criminal groups that share a common organizational structure and code of conduct. Similar to bribery, it can cause delays in handling crucial equipments, damage to site and social unrest throughout the construction.

3.3.2.7 Instability of Social Conditions

Various factors (such as political conflicts between two countries) can cause local people to have ulterior motives against the contractor causing a decrease in productivity amongst the employees.

3.3.2.8 Immaturity of Legal System

Maturity of the host country's legal system is crucial for interpreting and enforcing the laws in international constructions. An immature of legal system can cause delays and breaches affecting the construction adversely.

3.3.2.9 Restrictions for Foreign Companies

A contractor has to be aware of any legal or subtle restrictions applied to foreign companies working in the host country. These restrictions could decrease productivity, increase unit cost of resources, can cause delays in bureaucracy and site hand-over.

3.3.2.10 Unavailability of Material

Availability of building materials (such as cement, thermal protection, moisture protection, doors, surface finishing, furnishings, masonry, metals, plastics, wood, carpentry and many more) in the construction site is essential. Although some of these materials can be accessed locally, some of them may have to be imported from other countries. This has to be known by the contractor beforehand to take account of the additional cost and time delays to bring the material to the construction site.

3.3.2.11 Unavailability of Equipment

Construction equipments and heavy-duty vehicles (such as wheel loader, grader, scraper, landfill compactor, crane and bulldozers) are indispensable in construction sites. If some of these equipments cannot be obtained locally, they have to be imported and this has to be taken into account.

3.3.2.12 Unavailability of Labor

In construction, labor is composed of unskilled labors (involved in concrete pouring, paving, piping, demolition etc.) and skilled labors (used in masonry, carpentry and welding). It is possible that specialized skilled workers may not be hired locally from time to time. Even if this is possible, a language barrier can cause misunderstandings not to mention the potential cultural difference frictions. Therefore, for special tasks, labors may be hired from the mother country to overcome these problems. Inevitably, this may bring out new problems such as additional costs, paperwork, delay in bureaucracy and visa problems which could hold the project back.

3.3.2.13 Unavailability of Subcontractor

In the international construction projects, specialized local subcontractors are usually hired by the prime contractor to perform specific tasks as part of the overall project. The incentive to hire subcontractors is either to reduce costs or to mitigate project risks. However, if the construction site is in suburban areas, subcontractors in specific fields (electric, excavation, waterworks etc.) may be hard to find, and additional expenses may be necessary to hire them from other places or from abroad.

3.3.2.14 Unavailability of Infrastructure

Infrastructure (such as such as roads, water supply, sewers, power grids, telecommunications, and so forth) is very important for healthy operation of a project. It facilitates the production of goods and services; for example, roads enable the transport of raw materials to construction sites. Consequently, while working in remote areas, lack of infrastructure may cause a decrease in productivity, delays in work and extra expenditures in the delivery of services.

3.3.2.15 Complexity of Design

Some projects might have complex designs (such as nuclear, hydroelectric plants, chemical refinery plants, sophisticated factories, unique coastal structures) which may decrease the feasibility of the construction. Moreover, complex designs are more prone to make mistakes and have higher chance to create diversion among the project participants. These problems may result in decrease in productivity, increase in quantity of work (by remaking due to mistakes) and increase in cost of the project.

3.3.2.16 Incomplete Design

Incomplete design is one of the most important vulnerability factors that can have a drastic impact on the cost increase. If a construction process is started with a semi-finished project, it is quite possible to encounter some unforeseen problems. Working on a design as the construction proceeds may be very ineffective, because it may be necessary to undo tasks due to possible design modifications which cause additional expenses and waist of time.

3.3.2.17 Low Constructability

Even if a design is not complex and is fully complete, it does not mean that it will be easy to turn the ideas into reality on the construction field. Harsh geotechnical and weather conditions, working in limited areas can impede constructability which decreases productivity and thus increase project duration.

3.3.2.18 Design Errors

Design errors can potentially have big adverse effects in a project. It is very important to check a design several times and make sure that it does not have any errors before the construction starts because starting a project with a bad design (or with a false belief that it is complete) can have very dramatic effects depending on how serious the errors are. In general, design errors not only slow down the construction process, but they can also make some additional amendments necessary which cause loss of time and money.

3.3.2.19 Complexity of Construction Method

For some projects, such as specific industrial plants, complex construction methods and technologies are needed. This makes it necessary to hire qualified workers and to purchase advanced equipments resulting in additional expenses.

3.3.2.20 Poor Accessibility of Site

Logistics affect the duration of the project directly. Accessibility of the construction site has to be taken into account for the estimation of the time of shipping the materials and equipments, and transportation of personnel and even subcontractors. Poor accessibility of site which might be caused from heavy weather conditions or being far away from urban areas causes delays in logistics and affect the duration of construction.

3.3.2.21 Inadequate Geotechnical Investigation

Geotechnical investigations are performed by geotechnical engineers to obtain information on the physical properties of soil and rock around a site to design earthworks for proposed structures and for repair of distress to structures caused by subsurface conditions. A geotechnical investigation includes surface and subsurface exploration. Subsurface exploration usually involves soil sampling and laboratory tests of the soil samples retrieved. Specific project types such as pipelines that have deep foundation must have extensive geotechnical investigation. If this is not done, unexpected events may be encountered which will increase the construction time.

3.3.2.22 Inadequate Climate Conditions

Climate conditions include temperature, humidity, atmospheric pressure, wind, rainfall, atmospheric particle count and numerous other meteorological elements. The climate of a location is affected by its latitude, terrain, altitude, ice or snow cover (as well as nearby water bodies and their currents) and needs to be examined carefully in a project. Inadequate climate conditions can affect the work, and can cause delays in logistics and project termination dates.

3.3.2.23 Strict Quality Management Requirements

Quality management has three main components: quality control, quality assurance and quality improvement. Quality management focuses on product/service quality and the means to achieve it. This is accomplished by using quality assurance and control of processes/products. Having strict quality management requirements and frequent inspections in the construction site can cause the contractors to perform heavy paperwork in a project.

3.3.2.24 Strict Environmental Management Requirements

Environmental management involves the management of all components of relationships amongst all living species and their habitats. It has to be considered in a project plan also, because with strict requirements (such as working at specific hours due to noise and traffic, etc.) can cause the project to finish later than expected.

3.3.2.25 Strict Health and Safety Management Requirements

Health and safety management involves protecting the safety, health and welfare of people engaged in work. However, excessive amount of health and safety requirements in construction projects might decrease contractors' productivity.

3.3.2.26 Strict Project Management Requirements

Project management is the discipline of planning, organizing, and managing resources to bring about the successful completion of specific project while honoring the preconceived project constraints. Typical constraints are scope, time, and budget. In a construction project, the project management requirements need to be specified properly in advance, because if they are too strict, the productivity of the contractor will be adversely affected by the paperwork which may increase the construction time.

3.3.2.27 Vagueness of Contract Clauses

Contract is a legal agreement between the contractor and the client, and is enforceable by law or by binding arbitration with a specific remedy for breach. In a construction project, every clause in a contract needs to be written very carefully. From time to time, it has been observed that some important contract clauses are not written clearly and are vague. This may cause the project participants to have future misunderstandings and conflicts of interest which can lead to delays in the construction process.

3.3.2.28 Contract Errors

Errors in contract clauses can potentially have very serious consequences. Even though these errors may be produced unintentionally, they may create conflict of interest later on, and the partners may try to use them according to their own advantages. Trying to solve the contract errors as the construction proceeds lowers the motivation and productivity of all participants involved in the project. This may endanger the whole construction process.

3.3.2.29 Partner's Technical Incompetence

In a joint venture or consortium partnership, technically incompetent partners can affect the productivity of all participants directly or indirectly. The mistakes or delays of the incompetent partners slow down the construction process, and increase the cost of the project. Naturally, this decreases the confidence on the overall work as well.

3.3.2.30 Partner's Managerial Incompetence

Technical incompetence is not the only factor for a partner to work unproductively. Although the partner might have the necessary technical background or experience to handle the project, the partner's work may be slow and inefficient if it is motivated and managed poorly, or there exist disputes among its own staff. This will cause problems in the construction also.

3.3.2.31 Partner's Lack of Financial Resources

Financial resources are very important in construction business. A financially problematic partner can cause demoralization in the whole construction site and slow down the whole work. This can cause delays in the crucial tasks throughout the project.

3.3.2.32 Partner's Cultural Differences with the Company/Contractor

In a construction site, it is quite possible that the people working for companies and subcontractors come from various parts of the world. These people may have very different cultures, beliefs, life styles, modes of speaking and understanding, and languages. Yet, it is necessary to work with them efficiently, otherwise, these differences can potentially cause a lot of misunderstandings and even conflicts which can decrease productivity and cause delays in the project.

3.3.2.33 Designer's Technical Incompetence

Designer's technical competence can play an important role in the construction process. All designs are prone to errors and mistakes. It does not matter whether these errors are noticed before or after the construction starts, the contractor has to work with the designer to fix the problem. Naturally, the designer's technical competence plays an important role to minimize these efforts which costs time and money.

3.3.2.34 Designer's Managerial Incompetence

Every now and then, errors are found in the designs after the construction starts. Also, sometimes, it may be necessary to start a construction without fully completing the designs. In those cases, construction and design have to go simultaneously. If the designer has low managerial skills, amendments will be done slowly causing delays.

3.3.2.35 Designer's Lack of Financial Resources

Financial problems in the designers company can cause problems as well. Without sufficient financial power to hire qualified designer staff, productivity can decrease because with unqualified personnel it is more likely to make mistakes in the design. Also, if errors are found in the design after the construction starts, it will be difficult to fix them with unqualified personnel.

3.3.2.36 Designer's Cultural Differences with the Company/Contractor

Although at first glimpse, cultural differences between the designer and contractor firms may not seem as important as the other parameters, these differences may affect the relations between these two firms. Different holidays, beliefs and languages can cause delays and increase the chance to have misunderstandings.

3.3.2.37 Consultant's Technical Incompetence

A consultant is the "right-hand man" of a client at work. The client has confidence in consultant's expertise, and may ask for advice on any issue related with the project. Consequently, the consultant's technical competence becomes very important because it affects the client directly. The clients are usually not interested in checking everything by themselves in the field, and consultant's technical incompetence can slow down the work. Consider the case that a consultant does not appreciate the progress in the construction site and does not sign the paperwork. This can cause delays in progress payments and affect project participants' productivity.

3.3.2.38 Consultant's Managerial Incompetence

Managerial incompetence of the consultant can also cause productivity loss in the project. Suppose that all the technical issues are solved but the consultant has too much paperwork and bureaucracy to sign the papers for the contractor to receive the progress payment. This can slow down the progress and can possibly cause conflicts among the project participants.

3.3.2.39 Consultant's Lack of Financial Resources

A consultant's financial status may also affect a project. If a consultant firm has some financial problems and employs unqualified personnel, the client may easily be misguided. Naturally, this can adversely affect the project.

3.3.2.40 Consultant's Cultural Differences with the Company/Contractor

The contractor has close relations with the consultant in a project. The contractor receives progress payment at the end of every defined schedule after the consultants' approval. Naturally, big cultural differences (beliefs, holidays, language, etc.) between the consultant and contractor firms may possibly cause misunderstandings and conflicts by delaying the approvals.

3.3.2.41 Client's Lack of Clarity of Objectives

This is another parameter that has a very high chance to cause problems. Without well-defined objectives, scope of the whole project can change dramatically. This will inevitably affect all design aspects of the project, and can have a big impact on the project cost.

3.3.2.42 Client's Level of Bureaucracy

In order for a contractor to receive payments, client has to sign the required paperwork. With inefficient bureaucracy, additional paperwork could be involved and there could be delays in progress payments.

3.3.2.43 Client's Negative Attitude

Client's attitude towards the project or the contractor may change in time due to several reasons such as changes in the scope of the project or changes in political, economic, and social conditions. With the negative attitude, the level of bureaucracy may increase, requirements may be harsh, and delays in progress payments may occur. All these will affect the productivity of the project participants and the project.

3.3.2.44 Client's Poor Staff Profile

Although client hires consultants for advice, from time to time, client's own staff may also play a role in the project and make suggestions. In those cases, qualifications of these staff members can affect the whole project.

3.3.2.45 Client's Unavailability of Financial Resources

The entire project relies on the client's funding. Without client's financial resources, the project comes to a halt. Therefore, client's funding is probably the most important factor in international construction projects. Without proper funding, progress payments are delayed, productivity of the project participants decreases and the project duration increases.

3.3.2.46 Client's Technical Incompetence

When a client hires consultants, technical incompetence of client's own staff may not be very significant. However, in some projects, client's own staff is its consultant. At those times, technical incompetence of the client's own staff must be treated the same as the consultant's technical incompetence explained above.

3.3.2.47 Client's Poor Managerial/Organizational Ability

Although the client might have the funding and enthusiasm for the project, it should also have proper manageability and organization level to make smooth money transactions. Without proper management, there could be delays in progress payments.

3.3.2.48 Company's Lack of Experience in Similar Projects

There is a big difference between working on a specific type of project for the first time, and having worked on similar projects in the past. In the first time, a contractor may not be aware of crucial factors that need special attention, and many trials may be needed to gain experience. This can affect the duration and the budget of the project.

3.3.2.49 Company's Lack of Experience in Country

Working in a country for the first time can affect the progress. The contractor may be handicapped by some unforeseen circumstances, *e.g.* materials and equipments may not be obtained quickly, delays in bureaucracy might take place, management problems may be encountered, and different languages may cause misunderstandings.

3.3.2.50 Company's Lack of Experience in Project Delivery System

As mentioned previously, project delivery systems are of different types, namely, Design-Bid-Build, Design-Build, Design-Build-Operate-Maintain and Build-Operate-Transfer. Every delivery system has its own strengths and weaknesses, and if the contractor does not have sufficient experience with them, this can bring problems and may lead to decrease in productivity.

3.3.2.51 Company's Lack of Experience with Client

Working for a client for the first time is a big question mark. Naturally, the client will be skeptical towards the first-time contractor, and may bring extra paperwork to be on the safe side. These formalities could slow down the project.

3.3.2.52 Company's Lack of Experience with Partner

When a joint venture or consortium partnership is taken up, coherency among the partners can increase productivity. This could be hard at first, and it takes time for the companies to get used to and understand each other's strengths and weaknesses.

3.3.2.53 Company's Lack of Financial Resources

In a project, the contractor needs to pay the upkeep of its employees and expenditures in order to keep things on the track. Also, the contractor should always have sufficient funding on its own, in case there are delays in payments by the owner. Otherwise, under unexpected circumstances, the project may suffer from temporary financial problems to an unnecessarily large extent.

3.3.2.54 Company's Lack of Technical Resources

Technical resources affect the cost considerably. Without proper technical background, the company has higher probability to make mistakes which will lower its productivity. Moreover, frequent technical problems creates mistrust and conflicts among the partners in the construction field.

3.3.2.55 Company's Lack of Staff

No matter how strong the financial and technical background of the company is, without enough manpower, company cannot uphold high level of productivity because of delays and weariness in executing orders.

3.3.2.56 Company's Lack of Project Scope Management

Project scope in construction can be described as the work that needs to be accomplished to deliver the final product with the specified features. If not managed properly, incremental expansions in the scope of a project may take place which can affect the whole schedule and the budget.

3.3.2.57 Company's Lack of Project Time Management

It is very important to manage the time in accomplishing specific tasks, projects and goals in a project. This includes planning, allocating, setting goals, delegation, analysis of time spent, monitoring, organizing, scheduling, and prioritizing. Without proper time management, unpleasant variations can take place in the schedules.

3.3.2.58 Company's Lack of Project Cost Management

Cost management establishes budget of operations, processes and the analysis of variances or profitability. It is used to support decision-making to cut a company's expenditures and improve profitability. Elements that are taken into account by cost managements are raw materials, labor and indirect expenses/overhead costs. Without proper cost management, the budget can increase which can affect the whole project.

3.3.2.59 Company's Lack of Project Quality Management

As explained previously, quality management is composed of quality control, quality assurance and quality improvement. If the company has poor quality management, the quality of work will decrease which can increase the workload (because of remaking) and the project cost.

3.3.2.60 Company's Lack of Project Human Resource Management

Human resource management means employing people, utilizing and maintaining their services in tune with the job and organizational requirement. Lack of human resource management will adversely affect the employees and decrease their productivity.

3.3.2.61 Company's Lack of Project Communications Management

Communications management is the systematic planning, implementing, monitoring, and revision of all the communication channels within an organization, and between organizations. Communication management also establishes relations within other project participants. Without proper management, conflicts may occur among project participants and this may decrease productivity.

3.3.2.62 Company's Lack of Project Risk Management

Risk management in construction may be considered as the identification and assessment of risks followed by coordinated application of resources to minimize and control the probability and effects of unfortunate events. Therefore, improper risk management can produce very undesirable conditions which may increase the project cost.

3.3.2.63 Company's Lack of Project Procurement Management

Procurement in construction deals with the acquisition of goods and services at the best possible cost to meet the needs of the company in terms of quality and quantity, time, and location. Companies which have poor procurement management will have delays in logistics of the goods increasing the unit cost of the materials. This will result in delays and increase in project cost.

3.3.3 Risk Source/Event and Consequence Factors

3.3.3.1 Risk Sources

3.3.3.1.1 Currency Rates

The value of the host country's currency in terms of the home country's currency (*i.e.* currency rate) is also important. Depending on the countries' economic conditions or other factors, currency rates may change in a way to harm the contractors if goods need to be imported from other countries with foreign currencies. This can directly increase the unit costs of imported goods, and affect the project budget.

3.3.3.1.2 Inflation

Inflation is an increase in the general level of prices of goods and services over a period of time. When the price level rises, each unit of currency buys fewer goods and services; consequently, annual inflation is erosion in the purchasing power of money. Working in a country that has poor economical conditions will have a tendency of high inflation rates which may result in money loss for the company. In international construction, the companies must pay attention to the inflation in both the home and host countries.

3.3.3.1.3 Tax Rates

The tax rate describes the percentage at which the construction company is taxed. With poor economical conditions and a poor legal system in the host country, the tax rates could increase unexpectedly which can harm the company's project budget in an international construction.

3.3.3.1.4 Laws and Regulations

In an international construction project, the company should be thoroughly aware of the host country's laws towards the foreign companies, and also their implications related with the contract type (whether it is FIDIC, local regulations or project specific contract). No matter what the source is, adverse changes in the regulations can increase the paperwork which can cause delays in the logistics and bureaucracy. This may decrease the productivity in the project.

3.3.3.1.5 Relations with the Government

Depending on the political relations between the host country and the company's original country, attitude of the host country's government towards the international construction project may change adversely. With a negative attitude from the host country, bureaucracy, logistics, regulations, site hand-over, taxation might suffer severely resulting in loss of money and delays in project.

3.3.3.1.6 Relations with the Partner

If the project budget is high or if contractor companies are inexperienced in specific areas, contractors tend to be a partner in a joint venture or consortium. However, if the contractor does not work with partner companies in harmony, there may be problems in the exchange of services. Consequently, productivity in the project may decrease which can cause delays in the schedule.

3.3.3.1.7 Relations with the Consultant

The contractor needs to get consultant's approval to receive progress payments, and it is important that the contractor must be in good terms with the consultant. Bad relations between the contractor and the consultant can affect the bureaucracy and bring out delays in progress payments. This could negatively affect the whole project.

3.3.3.1.8 Relations with the Designer

Design errors, delays in completing the design, technical and managerial issues in the designer's office or complexity of construction techniques in the field can cause tension between the designer and contractor. With poor relations with the designer, there may be problems in the exchange of ideas. Consequently, quality of the work could decrease, and delays in project duration might occur.

3.3.3.1.9 Relations with the Client

Among all risk factors, the relation with the client is one of the most important ones. If these relations are bad, progress payments might be delayed, additional bureaucratic obstacle may be introduced, morale and productivity amongst the employees may fall down and conflicts with other project participants may arise.

3.3.3.1.10 Communication Between Parties

Contractor may be in good terms with all other project participants but if other parties have conflicts amongst themselves, the contractor itself will be affected as well. Harmony among all parties is essential in a joint project; otherwise, work quality can decrease.

3.3.3.1.11 Performance of the Partner

Technical, managerial or financial problems within the partner company can cause delays in the schedule of the work that they are responsible for. This will decrease productivity and the work quality in a joint project by affecting all participants' performances, and can cause money losses for all partners.

3.3.3.1.12 Performance of the Designer

This factor is similar to the performance of the partner, that is, poor performance of the designer (due to its managerial, technical and financial problems) could decrease the contractor's performance. If the designer's performance is poor, delays may occur, *e.g.* in making the design modifications, *etc.*

3.3.3.1.13 Performance of the Engineer

During a construction, it is necessary to solve all engineering problems properly, and engineer's approval is essential for the project to continue smoothly. If the engineer's performance is poor, conflicts may arise between the engineer and other employees. This might affect the company's overall productivity and could even hurt the relations with the client. This might cause delays in the bureaucracy and the progress payments, and increase the project duration.

3.3.3.1.14 Scope

Scope of the project may change adversely in time (mostly due to client's unclear objectives or other aspects) which can affect all other parameters related with the project. With additional requirements, there could be an increase in the workload, increase in unit cost of materials (if new equipments are required) and modifications in the design that can change the project cost entirely.

3.3.3.1.15 Design

Client's possible additional requirements or design errors may make it necessary to modify the design after the construction starts. This may require new materials and equipments, and increase the budget.

3.3.3.1.16 Construction Technology/Method

Modifications on the design or other effects (such as unexpectedly harsh climate), may make it necessary to improve the technology or the methods used in the construction site. This could decrease the productivity because the employees may not be accustomed with the new methods. This could cause delays in the work and additional costs to bring the equipments compatible with new technology into the site.

3.3.3.1.17 Client's Staff

Client's staff is responsible for monitoring the technical and managerial aspects of the project. If changes occur in the client's staff (if, for example, client's staff start working as engineer in the project), there may be conflicts with the participants and in technical issues, and this may affect the project.

3.3.3.1.18 Original Schedule/Sequence

Changes in the scope, design and performance of a project, distort the activities of the contractor (and its partners) and this may reflect as delays in the original project schedule. Consequently, there may be a decrease the productivity and economic conditions of the contractor because progress payments may be also delayed. This problem may not only increase the project duration, but may also gives rise to huge compensatory damages that have to be paid by the company.

3.3.3.1.19 Site Organization

Site organization refers to the organizational stage of the landscape design process. It involves the organization of land use zoning, access, circulation, privacy, security, shelter, land drainage, and other factors. This is done by arranging the compositional elements of landform, planting, water, buildings and paving and building in construction site plans. Without proper site organization, productivity may decrease considerably.

3.3.3.1.20 Project Team

Project team consists of project managers and technical office members that are directly working on the construction site. If unqualified personnel are employed in the project team due to financial or managerial problems of the company, decrease in quality of work could become inevitable.

3.3.3.1.21 Top Management (Company)

Project team is not the only party that can affect the company's performance. Top managers including the area director, chief executive officer and even the owner of the company can have effects on the construction. Having poor management from top managers will decrease the productivity of the employees and cause delays.

3.3.3.1.22 Availability of Labor

Depending on where the construction takes place, qualified or specialized workers may not be found in the host country. Moreover, in some countries, local people may not be hardworking or enthusiastic towards the project. Therefore, labor might have to be hired from the company's original country which will result in delays in logistics, additional costs and bureaucratic obstacles.

3.3.3.1.23 Availability of Material

Depending on the project type, specific materials might be needed in the construction. Working in developing countries, necessary materials might not be obtained locally and they may have to be imported from other countries. This will increase the cost of the unit prices and cause delays in the logistics.

3.3.3.1.24 Availability of Equipment

When special equipments such as tunnel boring machines and massive cranes are needed in a construction, it may be necessary to bring them from other countries. Importing these equipments will increase the cost significantly. Moreover, even after this equipment is obtained, if they break down, the construction comes to a halt until the spare parts come and this may take months, in some cases.

3.3.3.1.25 Availability of Subcontractor

In some cases, a qualified subcontractor may not be found locally, or even if it is found, it may not work efficiently. In these situations, hiring an international subcontractor becomes necessary. This increases the cost further, and necessitates request of additional time for the subcontractor to come to the site.

3.3.3.1.26 Public Reaction

In some projects, it may be necessary to work in a sensitive zone where there is a high risk of rebellion or strikes, or there may be a counter view which can cause the public to react negatively towards the project (*e.g.* building a nuclear power plant). In such cases, employees can be affected by the society which may decrease their productivity and the quality of the work.

3.3.3.1.27 Attitude of Client

Depending on many factors, the attitude and the enthusiasm of the client may decrease toward the contractor in time. This will negatively affect the productivity of the contractor employees, and may result in delays in progress.

3.3.3.1.28 Geological Conditions

If geotechnical investigations are not properly conducted, unexpected geotechnical conditions might be encountered during construction. Projects with very poor geological conditions need additional funding to overcome the problems (*e.g.* removing the rock layer). Also, if work is to be done mostly beneath the surface (such as building a subway system) additional time might be required to perform new geological surveys.

3.3.3.1.29 Site Conditions

Construction site conditions reflect the external factors that affect the construction site, and have to taken into account properly. Weather conditions such as heavy rains, very high or low temperatures can not only affect the productivity of the employees working in the construction field, but can also harm the equipments, lower the quality of the work, delay the logistics and many more.

3.3.3.1.30 Financial Situation of the Client

Depending on the world's economy and the host country's social conditions, the financial situation of the client may decline during the construction phase. This may cause delays in progress payments and may negatively affect the company and the productivity of the employees. Funding problems of the client may also affect the other project participants and the whole project.

3.3.3.1.31 Financial Situation of Company

Delay in the progress payments is not the only factor that will affect the financial situation of the company. The company may also have some internal financial problems caused by an increase in unit cost of the materials, for example. Again, this will decrease the productivity of the company and the quality of the work and can cause delays in schedules.

3.3.3.1.32 Financial Situation of the Partner

When working in a joint venture or consortium partnership, the financial situation of a partner may weaken. This may decrease the productivity of the partner, causing delays in the work that they are responsible for, and may affect the whole project.

3.3.3.1.33 Performance of Contractor

No matter what the adverse conditions are, the performance of the contractor is very important in handling a problem. Performance of the contractor greatly affects the productivity and the quality of the work in a project.

3.3.3.2 Unexpected Events

3.3.3.2.1 Social Unrest/Disorder

In an international construction project, social unrest may be encountered in a state lacking order. In such countries, employees working in the construction site are usually unqualified and have very low productivities. Also, there may be losses due to theft, and additional money must be spared for security.

3.3.3.2.2 War/Hostilities

War and hostilities give rise to lowest predictability and reliability in a project due to lack of safety. Productivity and work quality will be minimal, damage to sites can occur frequently, most of the materials might get lost or stolen during logistics.

3.3.3.2.3 Rebellion/Terrorism

In the regions where rebellion or terrorism is present, damages to sites can be frequent which can lower the productivity and the quality of work heavily because of the lack of safety. Also, in these situations, additional money might have to be spent for bribery.

3.3.3.2.4 Natural Catastrophes

Natural disasters (*e.g.* flood, tornado, volcanic eruption, earthquake or landslide) can drastically affect a construction project and lead to huge financial and human losses.

Consequently, the companies always secure themselves against natural catastrophes with clauses in the contract or insurance. Otherwise, in the case of a natural disaster, long delays in construction might take place, considerable amount of money might have to be spent for remaking, and productivity might suffer heavily.

3.3.3.2.5 Historical Findings

In some projects, such as the subway project in Istanbul, unexpected historical findings can cause long delays. In such cases, the construction process comes to a halt and the archaeologists possibly do some digging (for an indefinite time). The construction can proceed only after all the historical findings are carried to other locations. Naturally, compensation is necessary during the waiting period.

3.3.3.2.6 Accidents

Unfortunately, from time to time, accidents occur in construction sites. Some major accidents may even lead to loss of human lives because of ignorance or the lack of health and safety management within the company, *etc*. Such accidents decrease morale among the employees and the productivity and hurt the company financially. They may also make it necessary to have additional expenditures for compensation.

3.3.3.2.7 Damage to Equipments

Severe weather conditions or careless use can cause damages on the equipment. Sometimes, a good deal of time and money may need to be spent to bring spare parts. This may affect the project duration.

3.3.3.2.8 Theft

Theft can always happen in construction sites. If it is done on a large scale, it can negatively harm the project because loss of material may destroy the schedule. Replacement of stolen equipment results in waist of time and money, and hence, theft is always included in the contingency plans.

3.3.3.2.9 Strikes/Labor Problems

From time to time, strikes and other labor problems may occur in the construction sites because of lack of payment to employees or unfavorable social conditions. These problems need to be solved quickly because they may cause delays in the project and damage to sites.

3.3.3.3 Risk Events

3.3.3.3.1 Decrease in Productivity

Labor productivity is usually measured as a ratio of output from a production process per labor-hour. Several factors (mentioned previously) can adversely affect the productivity in a project. When that happens, delays may occur which may change the schedules. This may extend the project duration and may involve compensation for liquidated damages.

3.3.3.3.2 Increase in Quantity of Work

Changes in design or scope and remaking (by failing the quality checks) can increase the amount of work necessary to finish the job. This would produce an increase in the use of materials, labor, equipment and, hence, the cost.

3.3.3.3.3 Decrease in Quality of Work

Many factors explained above (such as poor managerial and technical incompetence, harsh climates, *etc.*) will lead to a decrease in the quality of work. If the quality is below a threshold, remaking has to take place which will increase the cost.

3.3.3.3.4 Increase in Unit Cost of Resources

Unit cost of the resources may increase due to several reasons. For example, along with the advances in the construction technology, it may be necessary to purchase new materials. Also, even if new materials are not needed, fluctuations in the currency rate might increase the unit cost of the resources. This will reflect in the total project cost inevitably.

3.3.3.3.5 Delay in Bureaucracy

If the host country has immature legal system, or the performance of the consultant is low, or client's staff is not efficient, there could be delays in bureaucracy. In such situations, extra time is needed to do the necessary paperwork, and extension in time may have to be requested.

3.3.3.3.6 Delay in Site Hand-Over

After completing the project, bureaucratic actions (with necessary paperwork) must take place in order to hand over the site to the client (or the host country when it is a public project). However, delays may occur in site hand-over, and if the delay is contractor's fault, liquidated damages may have to be compensated.

3.3.3.3.7 Delay in Logistics

As mentioned previously, during a construction, material, labor and equipment may need to be imported and even international subcontractors have to be hired, from time to time. There may be delays in the logistics of all these due to bureaucratic obstacles or harsh climate conditions, *etc*. Naturally, this will affect the entire project period.

3.3.3.3.8 Delay in Progress Payments

In a project, delays in progress payments might occur, if the partial work is not completed on time, if the client is in financial crisis, if the performance of the consultant is low, *etc*. In such a situation, if the contractor is also short on money, construction might slow down, productivity and thus quality of work might decrease.

3.4 Discussion of Factors Affecting Project Cost Increase

With the help of the survey that is put on the web, 52 projects are gathered. However, out of these 52 contributions, only 27 of them filled the survey completely. The other 25 contributions partially filled the survey and are not included in the database. Furthermore, 5 of the 44 surveys which are conducted in face-to-face interviews have missing parts as well. Concerned that the missing information might cause the system to give false predictions, these 5 projects are excluded from the database as well. A total of 96 projects are gathered during the data collection phase, but as stated before, 30 of them are excluded from the database and 66 of them are included. Names of the companies and number of the projects they have contributed are listed in Table 3.2.

Table 3.2 Companies and the number of projects used in the survey

Company Names	Number of the Projects	Company Names	Number of the Projects
Güriş İnşaat ve Mühendislik A.Ş	3	Nurol İnşaat ve Ticaret A.Ş	2
MNG İnşaat ve Ticaret A.Ş	3	Aydıner İnşaat A.Ş	1
EMTA İnşaat A.Ş	2	BM Mühendislik ve İnşaat A.Ş	1
Öztaş İnşaat A.Ş	2	Metiş İnşaat ve Ticaret A.Ş	1
MetişEpik JV	2	Kulak İnşaat Ticare ve Sanayi A.Ş	2
Yüksel İnşaat A.Ş	1	Be-Ha-Şe İnşaat Tic. San. LTD. Şti.	2
Zafer İnşaat ve Ticaret A.Ş	1	Tekfen Mühendislik A.Ş	2
As-ka İnşaat A.Ş	1	Tekfen Oz Gayrimenkul Geliştir. A.Ş	1
Özdoğan Enerji	1	AGE İnşaat ve Tic. A.Ş	2
Şahin Yapı Sanayi ve Tic. LTD.	1	Rönesans Şirketler Grubu	1
Mesa Mesken Sanayi A.Ş	2	Aydeniz İnşaat A.Ş	1
TMA Mühendislik LTD.	2	Kasktaş İnşaat A.Ş	1
GAMA Endüstri Tesisleri A.Ş	2	Yapı Merkezi İnşaat ve Sanayi A.Ş	2
YDA İnşaat Sanayi ve Tic. A.Ş	2	Projects that Recieved from the Web	52
		Total Number of Projects	96

CHAPTER 4

INITIAL CASE-BASE MODEL TO PREDICT COST OVERRUN

4.1 Developing a Case-Base Reasoning Model to Determine the Unexpected Cost Increase

After data have been collected, a case-base reasoning model has been developed to predict the unexpected cost increases in the projects.

4.1.1 ESTEEM Software

As Dikmen *et.al.* (2007) state "*the ESTEEM Case-Based Reasoning (CBR) development tool is a professional tool that allows developers, as well as non-programmers, to develop decision enabling applications built through the use of problem-solving experiences (cases)*". ESTEEM allows one to create the definition of what a CBR application is, how to retrieve the critical prior experiences, and how to use them in new situations. In this thesis, ESTEEM (version 1.4) has been used as a development tool. Figure 4.1 shows the main frame of the ESTEEM software.

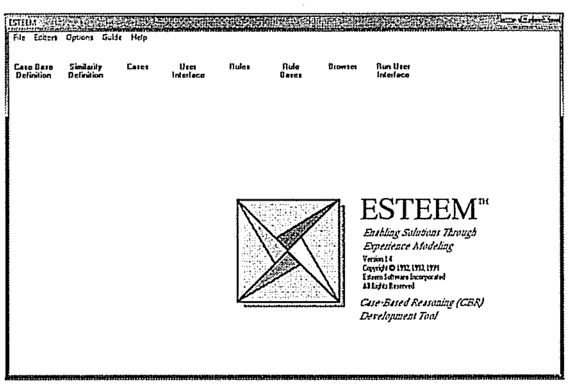


Figure 4.1 Main frame of the ESTEEM software.

4.1.2 Models Tested in ESTEEM

In this study, the risk and vulnerability ontology model developed by Fidan (2008) is used as the basis of the prediction model in which detailed information regarding the enhancing of the ontology can be found. Alternative models created on the basis of this ontology (IDEF diagrams) are shown in Figure 4.2.

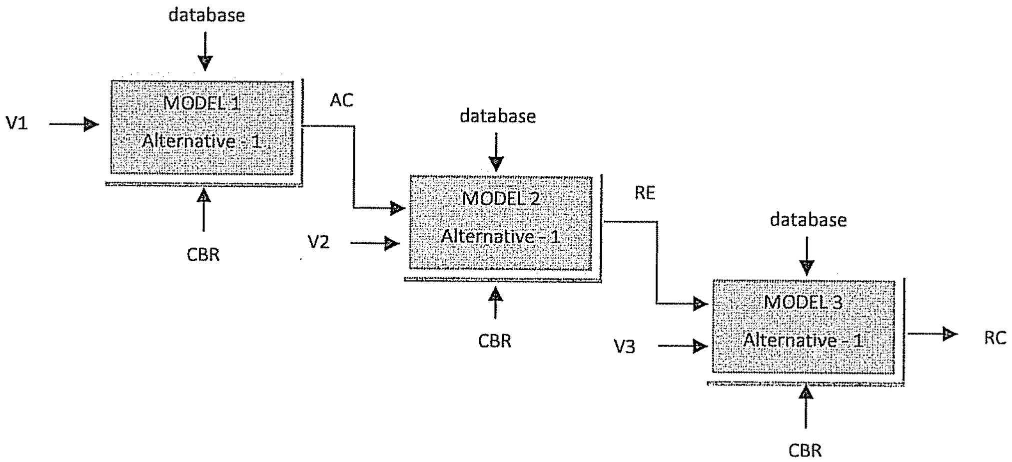
In the alternative-1, three models are created that are coherent with the link between risk and vulnerability explained in Fidan (2008). In Model 1, link between vulnerability (robustness) and adverse change parameters is formed. In the Model 2, after implementing the manageability factors (resilience) with the adverse change parameters, impacts of the adverse change parameters are determined and link between impacts and the risk event parameters is built. In Model 3, risk event parameters found in Model 2 are combined with the sensitivity parameters, and link to risk consequence is formed in order to predict unexpected cost increase.

In the alternative-2, two models are constructed. In Model 4, the Models 1 and 2 of alternative-1 are combined alongside with the adverse change parameters in order to find risk events. The output of Model 4 is then combined with the sensitivity parameters in Model 5 to predict the risk consequence. (Hence, one less model is used in alternative-2 as compared to alternative-1 in the prediction of the unexpected cost increase.)

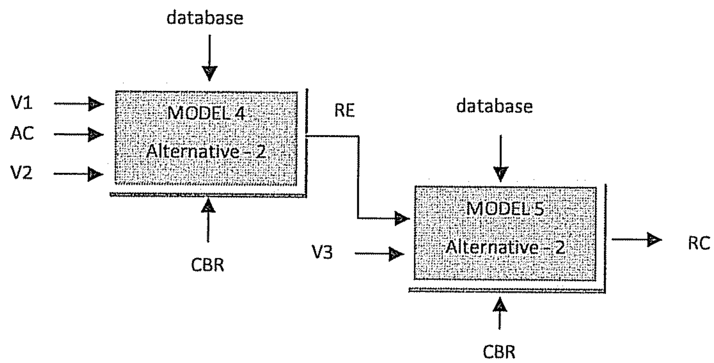
The alternative-3 consists of only one model. All of the vulnerability parameters (robustness, resilience and sensitivity parameters) are combined with the adverse change and risk events to link with the risk consequence in Model-6.

All the three alternatives are tested in order to find the most accurate prediction model. The best prediction model should have the minimum margin of error, and is recommended to be used to find the unexpected project cost increase in future projects.

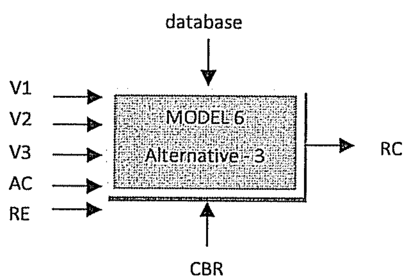
ALTERNATIVE – 1



ALTERNATIVE – 2



ALTERNATIVE – 3



Abbreviations and Respective Explanations:

V1 : Vulnerability Group 1 (robustness)
V2 : Vulnerability Group 2 (manageability)
V3 : Vulnerability Group 3 (resilience)
AC : Adverse Change
RC : Risk Consequence
RE : Risk Event
CBR: Case-Base Reasoning

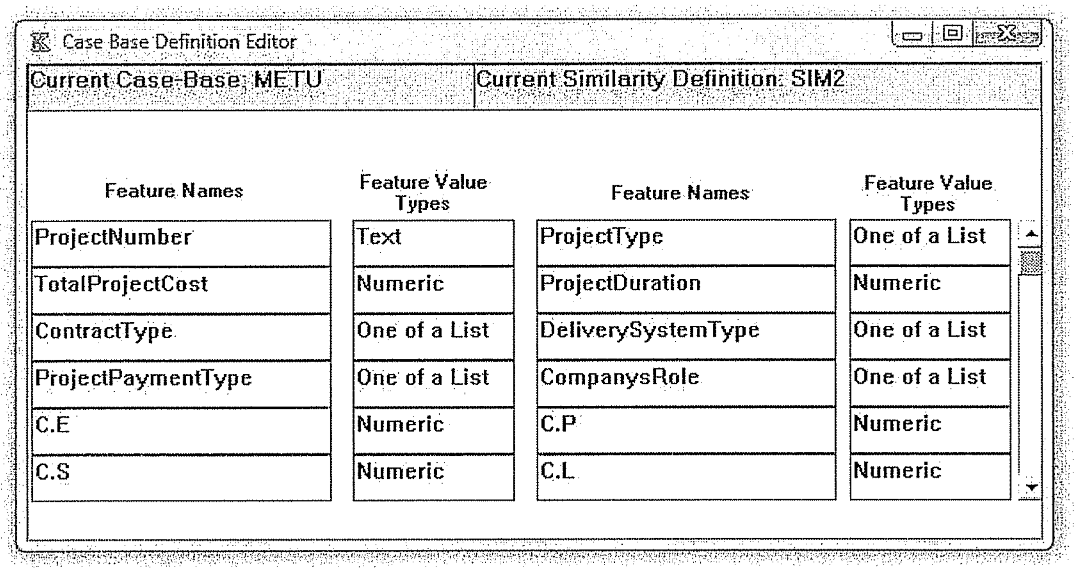


Figure 4.3 Some of the parameters (along with their types) used in the system.

4.1.3 How to Insert Parameters in ESTEEM

The parameters inserted in the ESTEEM software are of three types. "Text" type is used to name the projects saved in the system's database (*e.g.* Pr.1, Pr.2, *etc.*). Project type, contract type, project delivery system type, project payment type and company's role in the project are imported to the system as "One of a List" type. All other information about the projects (*e.g.* magnitude of the vulnerability and risk parameters such as economic conditions of the country, performance of the partner, financial situation of the client, *etc.*) is filled with the "Numeric" type using a scale from 1 (very low) to 5 (very high). Some of these parameters are shown in Figure 4.3.

4.1.4 Constructing the Similarity Method

Before constructing the similarity method, two crucial steps are needed to be taken. The first crucial step is to identify the importance factors for each parameter. In the ESTEEM software, three different similarity rules have been used. These are:

<u>Similarity Rule - 1:</u> All the parameters have equal importance weights. In other words, the importance factor for each parameter is 1.

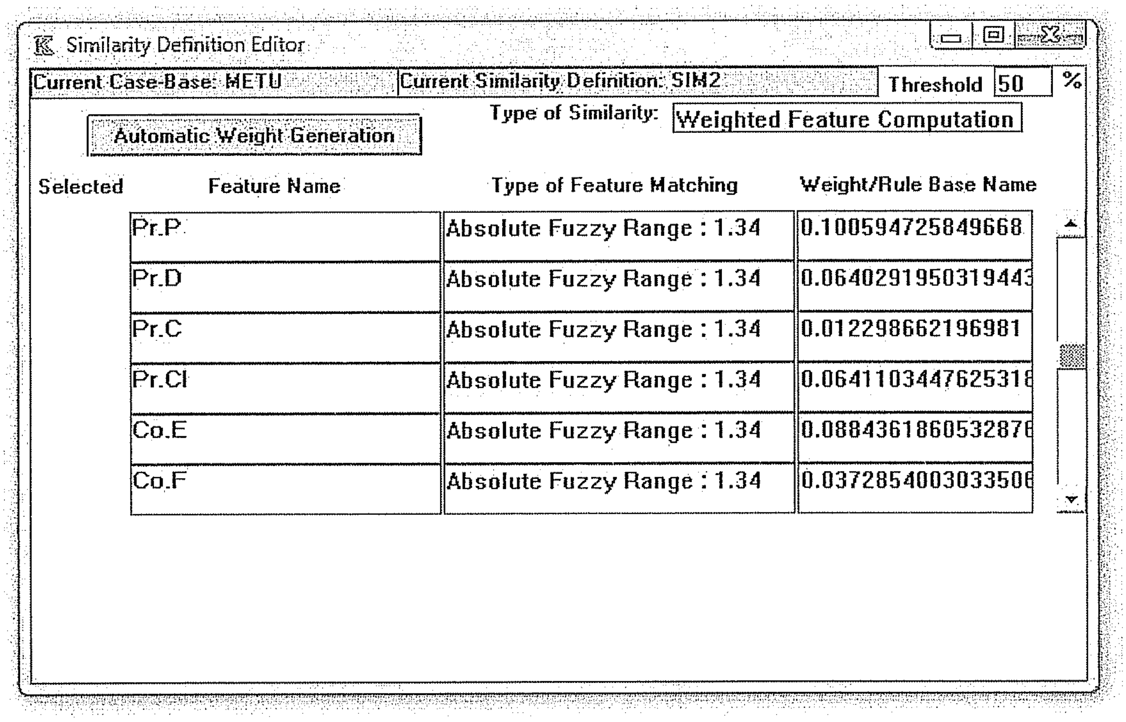


Figure 4.4 Example on how the system finds the importance weights for similarity rule – 2.

<u>Similarity Rule - 2:</u> ESTEEM checks the database and determines the importance weight for each factor from the projects that have already been saved. In the future, as the number of the projects increases in the database, the weight distribution will be more accurate. Figure 4.4 shows a small print screen on how the system has determined the importance weights from weighted feature computation.

<u>Similarity Rule - 3:</u> Importance weight for each parameter is determined by experts who participated in the survey. The average value for each parameter suggested by the experts is taken as the importance weight in similarity rule - 3.

The second crucial step is to figure out how close a specific parameter in one project is to the same parameter in another project. For example, how close are the parameters for two projects where one has high risk in economic conditions while the other has medium risk? Also, how similar are two projects when one is based on the Lump Sum payment and the other on the Unit Price?

The similarity system has two options based on how the parameter is identified in the system (whether the parameter is "One of a List" or "Numeric" type). As mentioned earlier, "Text" type is only used to identify the project, and therefore not used for similarity purposes. However, in "One of a List" type, differences between the options in the list are quiet distinct. A power plant project has whole lot of different vulnerability and risk factors than does a dam project. A cost-plus-fee payment type has its own pros and cons as compared to lump sum type. A subcontractor has different responsibilities and management requirements as compared to the sole contractor. Therefore, exact feature matching is used for "One of a List" types. If two projects have the same parameters (*e.g.* both are dam projects or both are joint venture partnerships), then a 100% similarity score is used, and when the parameters are different, the similarity score is 0%.

Using numeric parameters may lead to ambiguity. For example, "How similar are scores of 4 and 5?" or "What is the similarity rate between 1 and 3?". The similarity between two integer numbers (for all combinations) is asked to the experts where the numbers represent parameters under risk conditions. Experts have scored using very low, low, normal, high and very high risk rating factors. In the end, these are quantified by using numbers between 1 to 5, and the average of the experts' scores is taken. Absolute fuzzy range function with a range value of 3 has been accepted. The similarity rating for each risk value is shown in Figure 4.5.

4.1.5 Constructing the Prediction Methods

After constructing the similarity scores (to find which projects are similar based on the respective parameters), next step is to form the prediction method to evaluate the expected results for new projects. Nine prediction models are constructed and used in this thesis. The related prediction models are shown in Figure 4.6.

After forming the similarity and the prediction models, initial tests and initial findings are done which give a perspective on how the models work and show each model's strength and weaknesses.

Numeric Values		Similarity Rate based on Experts
1st Value	2nd Value	
1	1	100%
1	0 or 2	66%
1	3	33%
1	4 or 5	0%
2	2	100%
2	1 or 3	66%
2	0 or 4	33%
2	5	0%
3	3	100%
3	2 or 4	66%
3	1 or 5	33%
3	0	0%
4	4	100%
4	3 or 5	66%
4	2	33%
4	0 or 1	0%
5	5	100%
5	4	66%
5	3	33%
5	0 or 1 or 2	0%

Figure 4.5 Similarity rates based on experts

Figure 4.6	Prediction Method Types
Prediction Model - 1	The Parameters of the Most Similar Project
Prediction Model - 2	Average of the 5 Most Similiar Projects
Prediction Model - 3	Mode of the 5 Most Similiar Projects
Prediction Model - 4	Average of the 10 Most Similiar Projects
Prediction Model - 5	Mode of the 10 Most Similiar Projects
Prediction Model - 6	Average of the 15 Most Similiar Projects
Prediction Model - 7	Mode of the 15 Most Similiar Projects
Prediction Model - 8	Average of the 20 Most Similiar Projects
Prediction Model - 9	Mode of the 20 Most Similiar Projects

Figure 4.6 Prediction method types

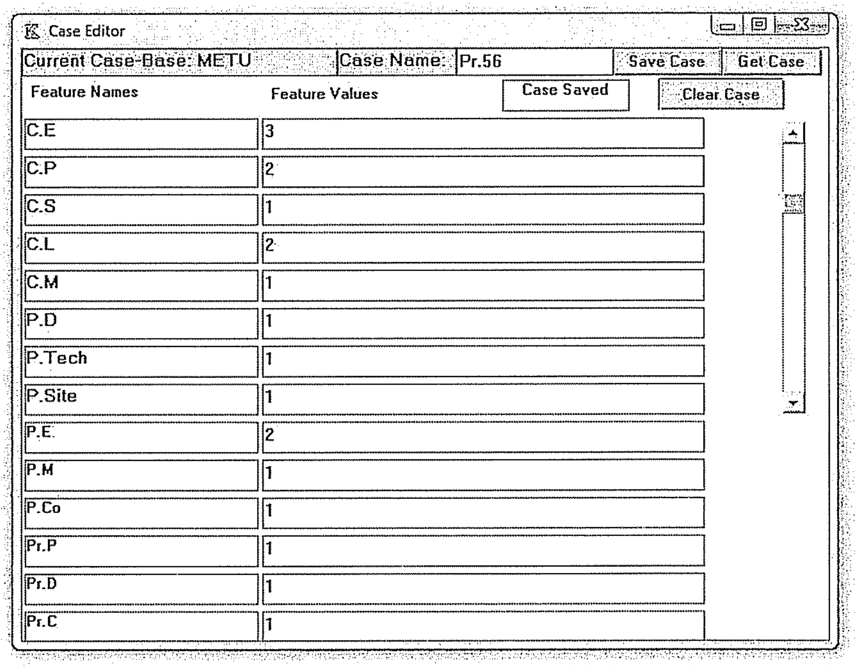


Figure 4.7 Saving project 56 (Pr.56)

4.2 Initial Findings

The 66 projects gathered with the help of the questionnaires are drawn together, and 85% of these projects (56 projects) are saved in the database of the ESTEEM software. Figure 4.7 shows how project 56 (Pr.56) is saved. The remaining 15% of the projects (10 projects) are left for testing proposes. The 85% - 15% cross-validation is described in detail in the next chapters. For now, suffice to say, the left out 10 projects are picked randomly from the 66 projects. After these 10 projects are tested, 10 other projects are chosen (again randomly) from the 66 projects, thus forming new testing samples. This is continued until each project is tested once.

First tests are constructed for the Model 1 of the alternative-1 (which follows the ontology order) shown in Figure 4.2. In other words, case-based reasoning model is formed in order to link the vulnerability – robustness parameters with the adverse change parameters. After excluding the randomly picked 10 projects, the other 56 projects are saved in the database. Then, each of the 10 excluded projects is tested one by one with each of the 56 projects to determine the similarity rates using each of the 3 similarity rules (*i.e.* a total of 10*56*3 tests are performed).

Adverse Changes	Tested Project	Projects That Are Found Similiar											
	Pr.62	20 (52%)	3	47	4	46	14	16	41	6	17	49	13
C.R	1	2	2	1	1	5	1	5	5	2	4	2	4
I	2	5	1	5	5	2	1	5	5	2	4	2	4
T.R	1	1	4	1	1	1	2	2	3	2	3	1	1
L.A.R	1	3	3	3	3	1	3	1	1	2	1	1	1
R.G	1	1	1	2	2	2	2	2	1	2	4	2	1
R.P	1	5	1	1	1	1	2	5	1	1	1	1	1
R.E	4	4	3	5	5	3	2	1	1	3	4	4	1
R.D	2	1	5	1	1	5	2	4	1	2	1	5	2
R.C	3	4	2	2	2	5	2	5	1	2	4	3	3
C.B.P	4	4	4	3	3	3	2	3	1	2	4	4	1
P.P	4	5	1	1	1	1	2	4	1	1	1	1	1
P.D	5	1	5	1	1	5	2	3	1	1	1	5	1
P.E	2	5	3	5	5	3	2	1	1	2	4	5	1
S	1	4	3	4	4	5	2	5	1	1	1	4	1
D	2	5	2	4	4	5	3	4	5	1	1	5	1
C.T.M	2	1	1	2	2	2	3	3	1	4	1	1	2
C.S	2	4	2	4	4	2	5	3	1	1	1	2	5
O.S.S	3	5	3	5	5	5	4	5	1	2	1	4	5
S.O	3	2	3	3	3	5	4	2	1	4	1	4	4
Pr.T	2	5	3	2	2	5	4	2	5	3	1	5	4
T.M	4	1	1	1	1	5	2	3	1	1	4	4	3
A.L	3	4	2	4	4	4	4	2	1	4	1	4	5
A.M	3	4	1	3	3	4	2	4	1	1	1	3	3
A.E	3	4	1	3	3	4	3	2	1	3	1	3	3
A.S	3	3	2	4	4	4	4	3	1	1	1	2	5
P.R	2	1	5	2	2	1	2	1	1	1	1	1	1
A.C	2	3	2	4	4	4	3	5	1	1	1	1	1
W.C	3	3	3	5	5	2	4	2	1	4	1	1	4
G.C	3	4	4	2	2	2	2	5	1	4	1	3	1
S.C	3	1	2	3	3	2	2	4	1	1	1	2	2
W.Q	2	1	2	3	3	2	2	4	1	1	1	3	4
F.S.C	3	1	1	5	5	3	2	1	1	1	4	4	1
F.S.Co	3	5	2	3	3	3	2	2	1	4	4	5	4
F.S.P	4	1	1	1	1	1	2	4	1	1	1	1	1
P.C	2	3	2	2	2	3	3	4	1	1	1	4	1

Figure 4.8 Example for the similarity conducted for Pr.62.

For one of the 10 excluded projects and using similarity rule 1 (all parameters with the same importance weights), similarity rates for the 56 projects in the database are calculated for sample test Pr.62. Figure 4.8 is the print screen of the output for Pr.62. The 2nd column from the left shows the detailed information for Pr.62 and the columns on its right are the 12 closest projects (starting with the most similar one) with their corresponding information. In this case, Project 20 is the closest one with 52% similarity rate. Similarity scores for the rest of the test samples are found likewise.

After finding the similar projects, five different methods have been used in prediction methods. These are: 1 - using the parameters of the most similar project, 2 - average of the 10 most similar projects, 3 - mode of the 10 most similar projects, 4 - average of the 20 most similar projects and finally 5 - mode of the 20 most similar projects.

Excel sheets are prepared for each prediction method. The actual values and predicted results for each prediction model for Pr.62 are shown in Figure 4.9 (for the alternative-1 Model 1). The result show that the best prediction method is Method 1 in this case.

Tested Project	Prediction Methods				
Pr. 62	Method -1	Method -2	Method -3	Method -4	Method -5
1	3	2,9	1	2,9	1
2	5	3,1	5	2,9	2
1	1	2,2	1	1,6	1
1	3	2,0	3	1,6	1
1	1	1,8	2	1,5	1
1	5	2,1	1	1,9	1
4	4	3,0	4	2,6	1
2	1	2,4	1	2,3	1
3	4	2,9	2	2,6	2
4	4	2,8	4	2,6	4
4	5	2,1	1	2,0	1
5	1	2,3	1	2,3	1
2	5	2,8	3	2,3	1
1	4	3,0	4	2,9	1
2	5	3,3	5	2,4	1
2	1	1,9	1	1,5	1
2	4	2,4	1	1,9	1
3	5	3,7	5	4,1	5
3	2	2,9	4	3,3	4
2	5	3,5	5	3,8	5
4	1	2,2	1	2,3	1
3	4	3,0	4	2,9	4
3	4	2,2	1	2,3	1
3	4	2,3	1	2,5	3
3	3	2,4	1	2,3	1
2	1	1,9	1	1,4	1
2	3	2,8	4	2,3	1
3	3	2,9	4	2,2	1
3	4	2,6	4	2,0	1
3	1	2,0	1	2,0	1
2	1	2,0	1	2,1	1
3	1	2,3	1	2,0	1
3	5	3,0	2	3,2	4
4	1	1,7	1	1,3	1
2	3	2,4	3	2,5	1

Figure 4.9 Prediction method results for Project 62

As might be seen from the figure, the prediction methods do not give highly accurate results. This is because the sample size is small (66 projects), but the number of parameters to find similarity is high (63 risk vulnerability–robustness input factors) and the number of parameters to be predicted is large (35 adverse change output factors). As a result of all these, it can not be expected that the models predict the outcomes with high precision, and models should be revised to ensure higher precision.The strategies used to revise the initial model, namely grouping of input parameters and further data collection are reported in the next chapter.

CHAPTER 5

REVISION OF THE INITIAL CASE-BASED PREDICTION MODEL

5.1 Grouping of Parameters:

In order to increase the similarity ratings, first the input and output parameters are grouped separately under common titles, as shown in Figure 5.1. This way the 63 risk vulnerability – robustness (input) parameters are reduced to 20; and the 35 adverse change factors (output) are reduced to 18.

Vulnerability - Robustness Factors	
1	Economic
2	Political
3	Social
4	Legal
5	Market (resource)
6	Design
7	Technology
8	Site Conditions
9	External factors
10	Management Requirements
11	Contract
12	Partner
13	Designer
14	Consultant
15	Client
16	Company's Experience
17	Company's Financial Conditions
18	Company's Technical Conditions
19	Company's Staff
20	Company's Manageability
Adverse Change (Risk Source) Factors	
1	Economic
2	Legal
3	Political
4	Partner
5	Consultant
6	Designer
7	Client
8	Plan
9	Scope
10	Technology
11	Staff
12	Market (resource)
13	Public Relations
14	External factors
15	Financial Conditions
16	Communication Between Parties
17	Performance of the Contractor
18	Company's Technical Conditions

Figure 5.1 Robustness and adverse change parameters after regrouping.

In this approach, the four vulnerability–robustness parameters related to the partner (technical incompetence, managerial incompetence, lack of financial resources and cultural differences with the company/contractor) are grouped under "Partner". Likewise, availability of labor, availability of material, availability of equipment and availability of subcontractor adverse change factors are grouped up as market (resource) risk source. Inevitably, new problems arise in grouping up the parameters. Consider the case in which technical incompetence, managerial incompetence, lack of financial resources and cultural differences with the company/contractor vulnerability ratings are, 1 – very low, 1 – very low, 2 – low, and 5 – very high respectively. One may ask, "What will be the partner robustness value after these four parameters are grouped as one? Will the new parameter be the average or are there any importance weights that should be taken into consideration?"

To handle this problem, two new sub-models are created by asking the participants (who contributed to the 66 projects) to asses the importance weights of the parameters before the questionnaire is used. In the first sub-model, the values given by individual participant are used. In the second sub-model, average values of the importance weights given by all the participants are taken for each parameter. The similarity rules and the prediction methods are kept the same. The results of the two sub-models for Pr.62 (for alternative-1, Model 1) are shown in Figures 5.2 and 5.3.

As can be seen from Figs. 5.2 and 5.3, similarity scores are higher than the ones in the ungrouped case. While the similarity ratio is 50% in the previous model, it is increased to approximately 60% in the new sub-models. However, it is clearly seen that the result is still less than satisfactory, and additional projects are needed. For additional projects, hypothetical cases are constructed

Tested Project	Prediction Methods				
Pr. 62	Method -1	Method -2	Method -3	Method -4	Method -5
1	2	2,6	2	2,6	2
1	1	2,3	3	2,3	1
1	1	1,9	1	2,1	1
3	4	2,3	1	2,0	1
3	3	3,0	3	3,0	3
4	1	2,7	1	2,8	1
3	2	3,0	3	3,0	3
1	1	3,5	1	3,3	1
2	1	3,1	1	3,1	1
2	1	2,1	1	2,7	1
3	5	5,0	6	4,5	5
3	5	3,1	5	3,3	3
3	2	3,0	2	2,9	2
2	1	1,9	1	2,1	1
3	1	2,7	4	3,1	1
3	4	3,4	4	3,6	4
4	5	3,3	4	3,1	4
2	4	2,6	4	2,5	1

Figure 5.2 Results for sub-model 1 (with 20 vulnerability – robustness and 18 adverse change parameters with the importance weights given by the individual only).

Tested Project	Prediction Methods				
Pr. 62	Method -1	Method -2	Method -3	Method -4	Method -5
1	3	2,6	3	2,7	3
1	3	2,1	1	2,0	1
1	4	1,8	1	1,9	1
3	3	2,5	4	2,1	1
3	5	3,2	3	2,8	3
4	5	2,8	1	2,9	1
3	4	2,6	2	2,9	3
1	5	3,0	4	3,2	4
2	5	3,4	1	3,1	1
2	5	2,4	1	2,1	1
3	5	4,9	5	4,4	5
3	1	3,5	5	3,2	5
3	4	3,2	2	2,7	2
2	4	2,2	1	2,0	1
3	2	2,7	3	2,7	1
3	2	3,8	4	3,5	4
4	3	2,8	4	3,0	4
2	1	2,7	1	2,7	1

Figure 5.3 Results for sub-model 2 (with 20 vulnerability – robustness and 18 adverse change factors with the average of the importance weights given by the participants).

5.2. Collection of Additional Data

As explained in Fidan (2008), a workshop was prepared in 2008 to test the feasibility and usability of the risk and vulnerability ontology in the field. In the workshop, there were six experts who had at least five years of experience in the international construction projects. In the present study, the same experts are called for a new workshop to create the hypothetical cases because it is important that the participants to be familiar with the present work and fully appreciate its purpose. Names of the experts are not given due to confidentiality reasons; however, the years of their experience, areas of specialization and the number of projects filled by them are given in Figure 5.4.

Hypothetical risk vulnerability – robustness factors are determined from the real projects through correlations. In the correlation phase, parameters that have effect on other parameters are determined, and hypothetical risk vulnerability factors are created through the correlation results. Calculations show that there is 88% of correlation accuracy between the hypothetical and the real cases. Each hypothetically created project is shown to the experts for approval asking whether these hypothetical cases are logical and consistent or not. The cases that are approved by the experts are added to the system and the rejected cases are excluded from the database. It should be kept in mind that the hypothetical cases are created from the real cases and cannot be formed without having sufficient amount of real projects.

Participant	Years of Practice	Area of Specialization	Number of Projects Filled
Expert A	19	Engineer	17
Expert B	15	Consultant	17
Expert C	15	Consultant	17
Expert D	9	Engineer	17
Expert E	6	Engineer	16
Expert F	5	Engineer	16

Figure 5.4 Information on the experts participated in the workshop.

As can be seen in the Figure 5.4, 100 hypothetical cases have been added to the system's database. With the 66 real projects and 100 hypothetical projects, a total of 166 projects are used in this study.

Results show that hypothetical cases do not negatively affect systems accuracy. Moreover, it has been proven that hypothetical cases increase the model's reliability and usability. This is shown in the examples listed below.

Example 1: Unexpected cost increase is to be predicted through the similarity and prediction models described in the previous chapters. In order to check the impact of the hypothetical cases on the systems predictability, a project with known project cost increase is chosen to be tested (Project 28). For the chosen project, alternative-1 method is tested. [In other words, Model 1 (vulnerability – robustness factors -> adverse change), Model 2 (adverse change -> risk event) and Model 3 (risk event -> risk consequence) are used in sequence.] Details of how the models work are described briefly in the next chapter. All these models are first tested by using only the real projects (66 projects), and later with the database that has the real and hypothetical cases (166 projects). Results are shown in Figure 5.5.

As can be seen, when 66 projects are used in the database, error rate for Project 28 is 14%. However, when the number of the projects in the database is increased by adding the hypothetical cases to the case library, error rate is decreased to 1.4%. Details on the calculations (CBR Results) are given in Appendix – B.

Figure 5.5	Project 28	CBR Results While Using Only the Real Cases		CBR Results While Using Both the Real and Hypothetic Cases	
		Calculated	Error Rate	Calculated	Error Rate
Unexpected Project Cost Increase	25%	39%	(39-25) = 14 %	23.6%	(25-23.6) = 1.4 %

Figure 5.5 Results on the error rates when using real cases alone and when using real and hypothetical cases together.

Figure 5.6	Real Case Data Set	Real + Hypothetic Case Data Set
Number of Similar Projects in the System	4 Projects	20+ Projects
Max. Similar Rate	73%	77%

Figure 5.6 Results on the similarity rates when using real cases alone and when using real case with hypothetical cases.

Example 2: Another benefit of the hypothetical cases is that they increase the similarity rate and the amount of similar cases that is found among the projects. In this example, Project 34 is chosen as the test case. Project 34 is again a real case and is tested to obtain the similarity rate and to find the number of similar projects in order to make a realistic prediction. Results are shown in Figure 5.6.

It can be seen that hypothetical cases not only increase the similarity rates but also increase the number of similar projects in the system, thus increasing the prediction reliability. Moreover, as shown in Figure 4.6, there are 9 different prediction methods used in the models which are: parameters taken as they are from the most similar case, average & mode of the 5 most similar cases, average & mode of the 10 most similar cases, average & mode of the 15 most similar cases and average & mode of the 20 most similar cases. When using the prediction methods for the data set having only the real cases, 4 similar projects are found. This prohibits the use of all the methods exercising 10, 15 and 20 most similar projects and cripples the methods using 5 most similar projects. Therefore, hypothetical cases not only increases the similarity rate but also provides additional similar projects to allow prediction methods to be used smoothly.

The average of the similarity rate is 70 % for the database formed by the real cases. However, this rate is increased to 75.5 % when hypothetical cases are also included. Maximum similarity ratings using the real cases alone and using both real and hypothetical cases are shown in Figure 5.7.

Project	66%	166%	Project	66%	166%	Project	66%	166%	Project	66%	166%	Project	66%	166%
1	83	83	41	65	65	81	60	70	121	57	57	161	57	73
2	77	77	42	80	80	82	65	85	122	68	75	162	70	75
3	75	77	43	73	73	83	68	74	123	76	76	163	64	80
4	78	78	44	85	85	84	60	68	124	70	77	164	65	72
5	85	85	45	72	72	85	77	77	125	65	73	165	72	78
6	78	78	46	65	65	86	57	63	126	57	68	166	68	70
7	80	80	47	83	83	87	70	70	127	73	77	AVE	70.04819	75.46386
8	82	82	48	73	73	88	74	76	128	0	72			
9	85	85	49	85	85	89	70	77	129	73	73			
10	82	82	50	83	83	90	73	73	130	70	82			
11	70	70	51	75	75	91	55	78	131	55	65			
12	82	82	52	68	73	92	67	70	132	73	78			
13	80	80	53	73	73	93	72	73	133	69	75			
14	80	80	54	75	83	94	75	75	134	70	77			
15	70	73	55	75	77	95	63	80	135	68	80			
16	63	63	56	70	75	96	60	65	136	60	63			
17	83	83	57	75	78	97	68	73	137	70	77			
18	78	78	58	79	83	98	76	76	138	55	66			
19	77	78	59	75	75	99	77	77	139	80	82			
20	60	80	60	85	85	100	65	73	140	68	72			
21	63	70	61	80	80	101	0	63	141	55	70			
22	83	83	62	87	87	102	65	75	142	70	82			
23	77	77	63	74	74	103	72	78	143	66	76			
24	83	83	64	75	78	104	72	72	144	73	77			
25	87	87	65	73	77	105	73	73	145	72	72			
26	78	78	66	68	68	106	60	80	146	50	68			
27	78	78	67	73	77	107	72	72	147	62	80			
28	73	73	68	68	84	108	69	72	148	62	68			
29	88	88	69	77	77	109	72	87	149	65	72			
30	82	82	70	65	78	110	68	72	150	70	77			
31	80	80	71	70	70	111	57	70	151	0	68			
32	80	80	72	80	80	112	72	75	152	65	73			
33	77	77	73	73	76	113	69	75	153	76	76			
34	73	77	74	70	75	114	68	77	154	63	70			
35	72	72	75	53	68	115	67	87	155	65	75			
36	65	65	76	57	63	116	65	65	156	57	63			
37	78	78	77	63	67	117	72	80	157	60	70			
38	70	70	78	69	73	118	75	75	158	70	77			
39	80	80	79	70	72	119	67	72	159	68	78			
40	85	85	80	65	72	120	78	76	160	77	77			

Figure 5.7 Maximum similarity rating for using only the real case and using real and hypothetical cases together.

Example 3: Actual values from the 66 real projects show that 57 of these projects have less than 50 % cost increase and only 9 of them have more than 50 %. This situation makes it difficult to predict the unexpected project cost increase for the future projects that might have high cost increase and this decreases the reliability and accuracy of the models. However, when hypothetical cases are included to the system, it is seen that 55 of them exceed the 50 % project cost increase rating. This makes it a lot easier for the model to predict the outcome by having additional projects to find similarity. Project cost increase and amount of projects gathered corresponding to that cost increase is shown in the Figure 5.8.

Number of Projects Gathered for Each Unexpected Cost Increase % (for 66 Projects)									
5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
8	10	5	11	8	2	3	7	2	1
55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
1	0	1	0	1	1	0	0	0	5
Number of Projects Gathered for Each Unexpected Cost Increase % (for 166 Projects)									
5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
8	15	10	22	13	10	6	15	8	4
55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
10	3	7	1	4	5	4	2	2	17

Figure 5.8 Project cost increase and amount of projects gathered in the corresponding interval both for real projects and for real and hypothetical projects together.

All these benefits allow the models to give a lot more accurate, reliable and feasible predictions when hypothetical projects are added to system's database. Details on the models and the results are shown in the next chapter.

CHAPTER 6

FINAL CASE-BASED REASONING MODEL FOR COST OVERRUN PREDICTION AND TEST RESULTS

6.1 Categorizing the Parameters

After collecting data from the real projects and creating the hypothetical cases, the parameters in these projects are categorized into five groups according to their types, as shown in Figure 6.1. Categorizing the parameters allows proposing several prediction models in the case-based reasoning software (by using different groups in different models). These models are checked and the most reliable one is determined as explained in the next sections.

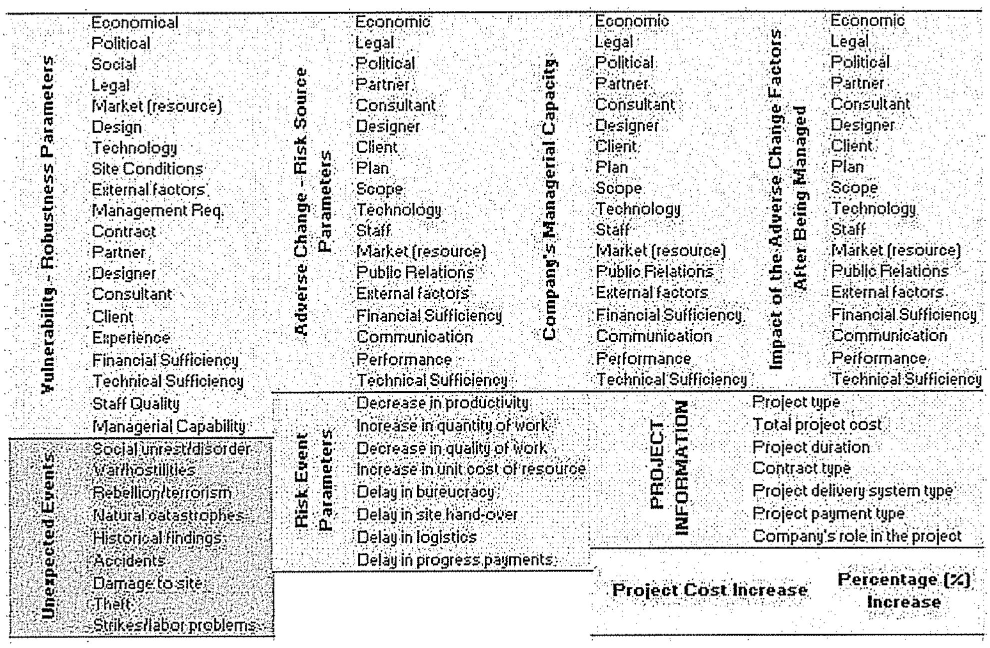


Figure 6.1 Categorization of the parameters.

6.2 Splitting the Projects into Five Sets

The reliability of the prediction models are tested using the cross validation technique. In this technique, the data set is split into smaller sets, and the system is tested for each of them. The mean and the standard deviation values are calculated for each small data set, and then averages of these values are taken for the error of the whole system.

In this study, projects are split into five smaller data sets. Projects in these data sets are picked randomly. Then, models are created with four of these data sets (which are also called *training sets*), and the excluded data set (*testing set*) is used to test the model's accuracy. After all projects in the testing set are tested, another set from the training sets is chosen as the testing set, and model is used again to check the accuracy. Cross validation technique is continued until all data sets are used as testing set once. This way reliability and accuracy of the models are tested for all the projects, and errors with their standard deviations are calculated for each model.

6.3 Alternatives Used in the ESTEEM

The alternatives used in this study are sketched in Fig. 4.2, and details are given in Chapter 4. In this chapter, results are presented for each of them.

6.3.1 Alternative-1

6.3.1.1 Structure of Alternative-1

In the case-based reasoning program (CBR –based RCAT), main frame of alternative-1 is formed from three case-based reasoning models and one rule-based model, as can be seen from Fig. 6.2. In Model 1, vulnerability–robustness factors (20 parameters) are used to predict risk source factors (18 parameters). After estimating the magnitude of the adverse changes, using the rule-based model, company's managerial capacities are determined (based on correlations); and impacts of the adverse changes on the project cost increase are estimated. In Model 2, impacts of the adverse changes (18 parameters) are used with unexpected events (9 parameters) to predict risk events (8 parameters). In Model 3, risk events are used to find the risk consequence which consists of only one parameter that is project cost increase.

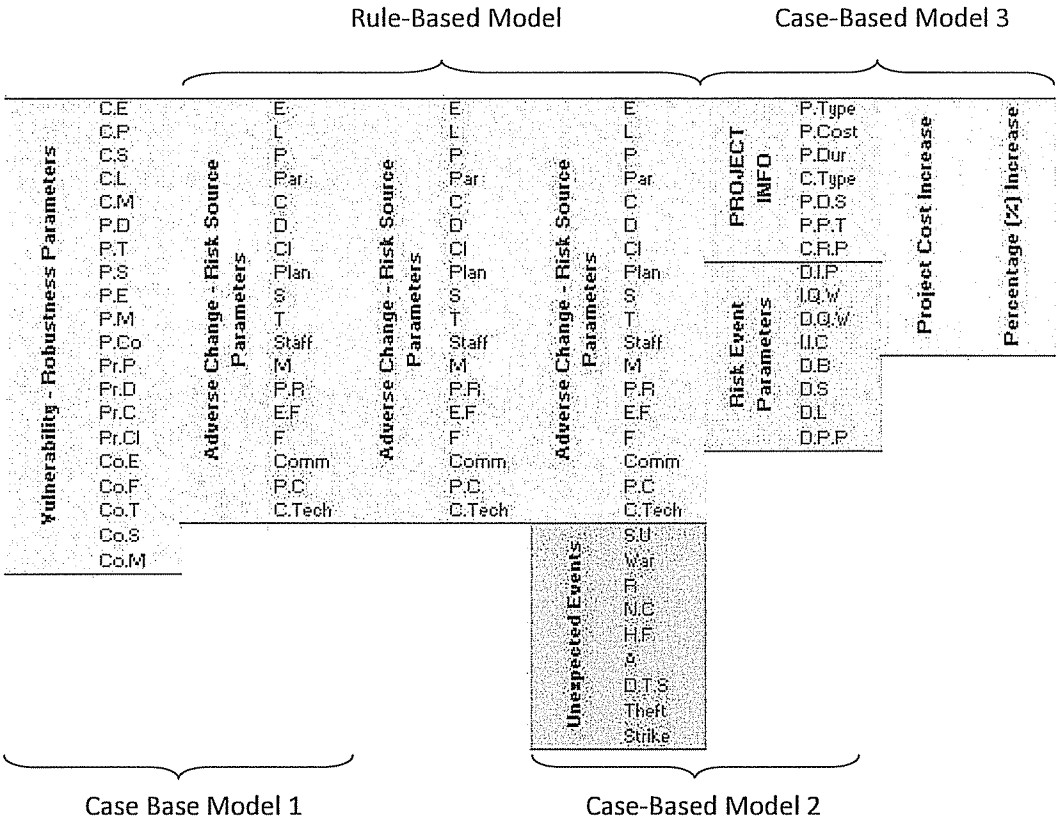


Figure 6.2 Structure for the alternative-1.

6.3.1.2 Research Findings for Alternative-1

6.3.1.2.1 Case-Base Model 1

With the formation of the model structure, cross validation technique is used to calculate each model's reliability by using each project in the testing set. As mentioned previously, three similarity rules are used to find similarity scores for each project. These are: Similarity 1 (with equal importance weight for each parameter), Similarity 2 (importance weights determined by the experts) and Similarity 3 (importance weights determined by ESTEEM based on the projects saved in the database). For every trial, 20 most similar projects given by ESTEEM are exported to Excel where prediction methods are used to compute the expected results.

MODEL 1 RELIABILITY RATE															
M1	Similarity 1					Similarity 2					Similarity 3				
	P.M1	P.M2	P.M3	P.M4	P.M5	P.M1	P.M2	P.M3	P.M4	P.M5	P.M1	P.M2	P.M3	P.M4	P.M5
Set #1	0.81	0.84	0.83	0.84	0.85	0.80	0.84	0.84	0.84	0.84	0.80	0.83	0.83	0.83	0.85
Set #2	0.81	0.83	0.83	0.83	0.83	0.81	0.83	0.83	0.83	0.83	0.80	0.83	0.83	0.83	0.82
Set #3	0.78	0.83	0.83	0.82	0.82	0.78	0.82	0.82	0.82	0.82	0.78	0.83	0.82	0.82	0.82
Set #4	0.80	0.84	0.81	0.84	0.82	0.80	0.84	0.82	0.83	0.82	0.78	0.84	0.82	0.83	0.82
Set #5	0.80	0.83	0.83	0.83	0.83	0.80	0.83	0.83	0.82	0.83	0.78	0.82	0.82	0.82	0.82
RESULT	0.8006	0.8331	0.8256	0.8304	0.8295 0.8239	0.7977	0.8325	0.8268	0.8300	0.8279 0.8230	0.7908	0.8319	0.8244	0.8271	0.8247 0.8198

Figure 6.3 Reliability rate for case-base Model 1.

Vulnerability-robustness parameters (20 parameters) are used to link with the adverse change (risk source) factors (18 parameters). After finding 20 most similar projects for each similarity rule, five different prediction methods (PM) have been used {keeping the same parameters for the most similar project (PM 1), average of the 10 most similar projects (PM 2), mode (most repeated value) of the 10 most similar projects (PM 3), average of the 20 most similar projects (PM 4) and mode of the 20 most similar projects (PM 5)}. Therefore, for each test project, 3 different similarity rules and 5 different prediction rules are applied. In other words, for each set, 15 different outputs are obtained. Considering the fact that each set is tested once, Model 1 is tested 75 times in order to find the best outcome. Figure 6.3 shows the reliability rate for each similarity rule with the corresponding data set. Clearly, the similarity rule that has the highest reliability rate (82.39%) is similarity rule 1 (parameters with equal importance weights). Moreover, prediction method chosen as the best alternative is PM 2 which is average of the 10 most similar projects.

After the most reliable method is chosen, the vulnerability factors for each project are imported to the system to receive magnitude of the adverse changes as outputs. Next step is to adjust the magnitude of the adverse changes in relation to their impact towards the project cost increase.

6.3.1.2.2 Rule Base Model

Magnitude of a risk source is not solely enough to determine its impact on a project. Managerial capacity of the company must be taken into account also because a problem may be more easily handled by some companies as compared to others. This may be clarified by the following example.

Suppose there are two construction companies that are faced with the same problem regarding the scope of the project (one of the adverse change parameters) and assume that the magnitude of the change in the scope is high (*e.g.* 4). The company that has never faced with this problem before and does not have the necessary technical and financial background to overcome the problem will have many problems, and there will be a big impact in the project cost. However, the other company that has past experience with the same problem and has high technical, financial and managerial capability may handle the problem more smoothly and may be able to reduce the effect of impact on the project cost.

To determine a proper rule based on the magnitude of the risk source (or in short magnitude) and managerial capability, correlations are found using the real projects. Results show that the rule written for managerial ability is 92.37% correlated with the real projects. Details regarding the rule is shown in Figure 6.4.

Collating Adverse Change with Resilience		Impact of the "change" on the cost after managed
Risk Source	Manageability Level	
0	-	0
1	1 to 5	1
2	1 to 3	2
2	4 or 5	1
3	1 or 2	4
3	3	3
3	4	2
3	5	1
4	1 or 2	5
4	3	4
4	4	3
4	5	2
5	1 to 3	5
5	4	4
5	5	3

Figure 6.4 Basis for the rule-based model.

As can be seen from the figure, a risk source with a high magnitude (4) may have a low impact (2) on a project cost if managed properly (5). Otherwise (*i.e.* manageability level ≤ 2), the impact will be more (5) than the magnitude (4).

After the impact for each adverse change on the project cost is determined, the second case-based model is used in order to calculate the risk event parameters.

6.3.1.2.3 Case-Base Model 2

Risk source parameters are formed from adverse changes (18 factors) caused by human faults and unexpected situations (9 factors) that are force majeure. In Model 2, these two groups are gathered to link with the risk events (8 parameters). The similarity and prediction methods used in Model 1 is used in Model 2 as well. Therefore, Model 2 is also tested 75 times in order to find the best solution. Results for reliability of Model 2 are shown in Figure 6.5.

This figure shows that the similarity rule that has the highest reliability rate (86.56 %) is similarity rule 2 (where importance weights are determined by the experts). Moreover, the prediction method chosen as the best alternative is PM 3 (which is mode of the 10 most similar projects) with 87.23% reliability.

After the most reliable method is chosen, the risk sources (both adverse change and unexpected events) are imported to the system to receive outputs as risk events. Final model in this alternative links risk event parameters with risk consequence (unexpected cost increase).

MODEL 2 RELIABILITY RATE															
M2	Similarity 1					Similarity 2					Similarity 3				
	P.M1	P.M2	P.M3	P.M4	P.M5	P.M1	P.M2	P.M3	P.M4	P.M5	P.M1	P.M2	P.M3	P.M4	P.M5
Set #1	0.85	0.87	0.88	0.87	0.88	0.85	0.87	0.87	0.87	0.87	0.83	0.87	0.88	0.87	0.87
Set #2	0.84	0.87	0.87	0.86	0.88	0.84	0.87	0.87	0.87	0.89	0.84	0.87	0.86	0.86	0.87
Set #3	0.85	0.86	0.86	0.86	0.86	0.86	0.86	0.87	0.86	0.86	0.85	0.86	0.86	0.86	0.86
Set #4	0.86	0.87	0.87	0.87	0.87	0.86	0.87	0.88	0.87	0.88	0.85	0.87	0.88	0.87	0.88
Set #5	0.85	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.85	0.87	0.87	0.86	0.86
RESULT	0.8488	0.8655	0.8688	0.8629	0.8683	0.8532	0.8659	0.8723	0.8644	0.8720	0.8468	0.8674	0.8692	0.8639	0.8697
					0.8629					0.8656					0.8634

Figure 6.5 Reliability rate for case-base Model 2.

6.3.1.2.4 Case-Base Model 3

In alternative-1, final step is to link risk events (found in Model 2) and project information (sensitivity factors) to obtain risk consequence (in order to predict unexpected project costs for the projects). Similarity rules used in Models 1 and 2 are used in Model 3 as well, however, different prediction methods are used. Note that the scales for the modes (used in the prediction methods) in Models 1 and 2 are between 1 and 5, but in the case of Model 3 the scale for the percentage of unexpected project cost incre is (0-100) which is is too big for the mode to be used in prediction analysis. Therefore, additional average rules are implemented to prediction methods. In Model 3, five prediction methods have been used. These are obtained by using the same parameters for the most similar project (PM 1), average of the 5 most similar projects (PM 2), average of the 10 most similar projects (PM 3), average of the 15 most similar projects (PM 4) and average of the 20 most similar projects (PM 5). Figure 6.6 shows that, for Model 3, there is a 10.2886 % error rate for the prediction of unexpected cost increase when similarity rule 1 is used (all parameters have the same importance weight). Moreover, error rate is decreased to 8.5561 % when PM 4 (average of the 15 most similar projects) is used.

The present results for alternative-1 show that if this program is used during the tendering stage (based on the vulnerability – robustness parameters and project & firm information), the predicted project cost increase value will be within the +/- 8.5561 % range of the actual value of the forthcoming project.

MODEL 3 ERROR RATE															
M3	Similarity 1					Similarity 2					Similarity 3				
	P.M1	P.M2	P.M3	P.M4	P.M5	P.M1	P.M2	P.M3	P.M4	P.M5	P.M1	P.M2	P.M3	P.M4	P.M5
Set #1	20.85	9.97	9.64	9.31	9.43	23.09	12.91	12.01	12.39	12.82	19.26	12.74	11.32	12.18	12.26
Set #2	13.03	10.36	9.63	8.81	9.24	17.12	12.61	11.48	11.35	11.42	11.82	12.12	10.92	11.45	11.11
Set #3	14.24	8.41	8.01	7.83	8.58	12.58	10.64	11.50	12.53	13.02	12.27	11.97	10.94	11.17	12.06
Set #4	13.42	9.30	10.12	8.31	8.64	16.82	12.52	11.12	10.71	11.17	14.39	11.70	11.14	11.96	11.69
Set #5	14.52	9.61	9.08	8.53	8.35	15.88	13.67	13.09	13.37	13.11	15.30	12.52	12.77	12.97	13.12
RESULT	15.2130	9.5311	9.2967	8.5561	8.8459	17.0964	12.4672	11.8423	12.0704	12.3086	14.6105	12.2077	11.4193	11.9464	12.0484
					10.2886					13.1570					12.4464

Figure 6.6 Reliability rate for case-base Model 3.

Fig. 6.7	MODEL 3 SIMILARITY RULE 1 PREDICTION RULE 4 ERROR ANALYSIS	
	Error Ave.	Error Stand. Deviation
Set #1	9.3135	7.73
Set #2	8.8182	7.24
Set #3	7.8388	8.58
Set #4	8.3145	6.81
Set #5	8.5361	6.05
RESULT	8.5642	7.2842

Figure 6.7 Errors and standard deviations for Model 3.

Fig 6.8	Similarity Rule Chosen	Prediction Method Chosen
Model 1	All Parameters Have Equal Importance Weight	Average of the 10 Most Similiar Projects
Model 2	Importance Weights for Each Parameter is Determined by Experts	Mode of the 10 Most Similiar Projects
Model 3	All Parameters Have Equal Importance Weight	Average of the 15 Most Similiar Projects

Figure 6.8 Similarity and prediction methods chosen for each model in alternative-1.

Average error and error standard deviation for each data set for Model 3 - similarity rule 1 - prediction rule 4 are shown in Fig. 6.7. To sum up, for alternative-1, similarity rules and prediction methods chosen for each model is shown in Figure 6.8.

When these rules and methods are used, the error rate for the prediction of unexpected cost increase comes out to be 12.71 % at first. However, this value can be decreased to 8.56 % by introducing a couple of changes. Considering the fact that there were only three actual projects that had more than 100 % cost increase, an upper limit of 100 % is put for the predicted cost increase and the projects that have more than 100 % cost increase is adjusted to this upper limit.

Secondly, in hypothetical cases, cost increase percentage results were in 1 % sensitivity. However, in real cases, results were gathered with 5 % sensitivity. Changing the sensitivity values of hypothetical cases from 1% to 5% (as in the case of real cases) helped to improve the accuracy of the results as well.

6.3.1.3 Research Findings for Alternative-2

6.3.1.3.1 Case-Base Model 4

As shown in Figure 4.2, alternative-2 is composed of two models. In Model 4, vulnerability – robustness factors (20 parameters), adverse change factors (18 parameters) and unexpected events (9 parameters) are linked to give outputs which are the risk events (8 parameters). The main difference between alternatives 1 and 2 is that Model 4 in alternative-2 is a combination of Model 1, rule base model and Model 2 in alternative-1. Hence, the same similarity and prediction rules are used in both alternatives. The results are tested 75 times in order to find the best similarity and prediction rule for Model 4.

Figure 6.9 shows the reliability rate results for Model 4. Clearly, similarity rule 3 gives the highest reliability. In other words, for this model, when ESTEEM determines the importance rate for each parameter, reliability rate comes out to be the highest (84.19 %). Moreover, when prediction method 2 (average of the 10 most similar projects) is used; reliability rate increases to 85.49%. Considering the fact that both Models 2 and 4 predict the values for risk events, a comparison is made and it is seen that the result of Model 2 (87.23 %) is greater, as shown in Figure 6.5. This shows that determining each step chronologically just the same as in the construction sites by implementing additional case base and rule base models improves the reliability.

After risk events have been computed for Model 4, link between risk events and consequences is formed in Model 5 to find the project cost increase.

MODEL 4 RELIABILITY RATE															
M1	Similarity 1					Similarity 2					Similarity 3				
	P.M1	P.M2	P.M3	P.M4	P.M5	P.M1	P.M2	P.M3	P.M4	P.M5	P.M1	P.M2	P.M3	P.M4	P.M5
Set #1	0.83	0.86	0.83	0.86	0.84	0.81	0.85	0.82	0.85	0.83	0.82	0.86	0.83	0.86	0.85
Set #2	0.82	0.86	0.83	0.86	0.83	0.81	0.84	0.82	0.84	0.83	0.82	0.86	0.85	0.86	0.85
Set #3	0.82	0.85	0.85	0.85	0.85	0.78	0.84	0.83	0.84	0.83	0.83	0.85	0.85	0.84	0.84
Set #4	0.81	0.85	0.85	0.85	0.84	0.77	0.84	0.83	0.84	0.84	0.82	0.86	0.85	0.86	0.85
Set #5	0.83	0.84	0.85	0.84	0.83	0.80	0.84	0.81	0.84	0.81	0.82	0.84	0.83	0.84	0.82
RESULT	0.8203	0.8542	0.8405	0.8516	0.8390 0.8411	0.7933	0.8411	0.8221	0.8408	0.8266 0.8248	0.8220	0.8549	0.8399	0.8502	0.8426 0.8419

Figure 6.9 Reliability rate for case-base Model 4.

6.3.1.3.2 Case-Base Model 5

Similar to Model 3, Model 5 predicts the unexpected cost increase through risk events and firm and project information (sensitivity parameters). Therefore, the same similarity and prediction rules used in Model 3 are applied to Model 5. Results are shown in Figure 6.10.

This figure shows that similarity rule 2 gives the lowest error rate. In other words, when experts determine the importance weights for each parameter, error rate for the prediction of unexpected cost increase comes out to be 16.4120 %. Moreover, error rate is decreased to 16.0366 % when prediction model 5 (average of the 20 most similar projects) is used.

The present results for alternative-2 show that if this program is used during the tendering stage (based on the vulnerability – robustness parameters and project & firm information), the predicted project cost increase value will be within the +/- 16.0366 % range of the actual value of the forthcoming project.

MODEL 5 ERROR RATE															
M3	Similarity 1					Similarity 2					Similarity 3				
	P.M1	P.M2	P.M3	P.M4	P.M5	P.M1	P.M2	P.M3	P.M4	P.M5	P.M1	P.M2	P.M3	P.M4	P.M5
Set #1	16.76	14.00	12.65	12.81	13.11	18.82	14.29	12.94	12.91	12.46	25.60	21.23	19.92	20.29	21.08
Set #2	13.64	14.18	13.27	13.67	13.39	12.42	14.42	13.98	12.96	13.42	19.38	17.76	18.82	19.38	20.95
Set #3	20.45	19.33	20.33	21.13	21.14	18.48	18.91	19.47	19.91	20.26	24.82	18.73	19.22	19.51	19.78
Set #4	16.21	15.18	15.38	15.96	16.41	16.52	15.33	16.20	16.18	16.36	24.11	20.36	22.46	22.45	22.89
Set #5	21.55	19.73	18.70	18.11	18.19	20.18	19.39	18.27	18.51	17.68	38.88	31.45	38.69	39.85	38.95
RESULT	17.7226	16.4848	16.0658	16.3365	16.4478 16.6115	17.2859	16.4709	16.1731	16.0335	16.0366 16.4120	26.5570	21.9186	23.8196	24.2974	24.7327 24.2651

Figure 6.10 Reliability rate for case-base Model 5.

Fig. 6.11	MODEL 5 SIMILARITY RULE 2 PREDICTION RULE 5 ERROR ANALYSIS	
	Error Ave.	Error Stand. Deviation
Set #1	12.4632	10.35
Set #2	13.4242	11.03
Set #3	20.2576	18.50
Set #4	16.3561	13.41
Set #5	17.6818	12.52
RESULT	16.0366	13.1613

Figure 6.11 Errors and standard deviations for Model 5.

Fig 6.12	Similarity Rule Chosen	Prediction Method Chosen
Model 4	Importance Weights for Each Parameter is Determined by ESTEEM	Average of the 10 Most Similiar Projects
Model 5	Importance Weights for Each Parameter is Determined by Experts	Mode of the 20 Most Similiar Projects

Figure 6.12 Similarity and prediction methods chosen for each model in alternative-2.

Average error and error standard deviation for each data set for Model 5 - similarity rule 2 - prediction rule 5 are shown in Fig. 6.11. To sum up, for alternative-2, similarity rules and prediction methods chosen for each model is shown in Figure 6.12.

However, the error rate of Model 5 is nearly twice the error rate of Model 3 (as can be seen from Figures 6.11 and 6.7, respectively). Therefore, it is concluded that alternative-2 is not as feasible and reliable as alternative-1.

6.3.1.4 Research Findings for Alternative-3 (Case-Base Model 6)

As shown in Figure 4.2, the last alternative which is alternative-3 is composed of only one model. In Model 6, all the vulnerability factors (robustness, resilience and sensitivity parameters) as well as risk sources (adverse changes and unexpected situations) with risk events are combined into one single model in order to find risk consequence which is project cost increase. In this model, all parameters are grouped without considering the chronological orders in construction sites, and implemented simultaneously. As in the case of other models, it consists of three similarity rules. Moreover, because the output scales of Models 3, 5 and 6 are equal, the same prediction rules are applied in Model 6. The results are again tested 75 times in order to find the best similarity and prediction rule for Model 6.

Figure 6.13 shows that similarity rule 1 gives the lowest error rate. In other words, when all the parameters have equal importance weights, error rate for the prediction of unexpected cost increase comes out to be 17.5777 %. Moreover, error rate is decreased to 16.6277 % when prediction model 3 (average of the 10 most similar projects) is used.

MODEL 6 ERROR RATE															
M3	Similarity 1					Similarity 2					Similarity 3				
	P.M1	P.M2	P.M3	P.M4	P.M5	P.M1	P.M2	P.M3	P.M4	P.M5	P.M1	P.M2	P.M3	P.M4	P.M5
Set #1	20.26	19.35	15.93	16.97	16.90	22.76	19.62	18.07	17.90	19.03	24.53	16.41	16.09	16.25	17.21
Set #2	18.27	16.45	13.39	13.36	13.98	21.76	16.82	16.83	15.56	15.77	19.64	16.06	13.73	13.94	13.06
Set #3	22.82	19.33	20.48	20.59	21.06	28.42	21.70	21.83	23.82	23.37	21.06	21.42	21.52	22.48	22.55
Set #4	19.48	15.42	17.39	18.02	17.45	26.76	20.48	19.04	18.04	18.56	20.55	16.61	17.08	17.23	16.86
Set #5	15.97	15.45	15.94	18.15	16.99	19.91	15.76	17.41	17.35	18.27	16.00	16.15	16.48	17.80	16.91
RESULT	19.3620	17.2039	16.6277	17.4191	17.2759 17.5277	23.9226	18.8750	18.6373	18.5333	19.0004 19.7937	20.3544	17.3296	16.9789	17.5395	17.3170 17.9039

Figure 6.13 Reliability rate for case-base Model 6.

Fig. 6.14	MODEL 6 SIMILARITY RULE 1 PREDICTION RULE 3 ERROR ANALYSIS	
	Error Ave.	Error Stand. Deviation
Set #1	15.9265	13.22
Set #2	13.3939	11.00
Set #3	20.4848	18.71
Set #4	17.3939	14.26
Set #5	15.9394	11.29
RESULT	**16.7056**	**13.6962**

Figure 6.14 Errors and standard deviations for Model 6.

Fig 6.15	Similarity Rule Chosen	Prediction Method Chosen
Model 6	All Parameters Have Equal Importance Weight	Average of the 10 Most Similiar Projects

Figure 6.15 Similarity and prediction method chosen for the model in alternative-3.

The present results for alternative-3 show that if this program is used during the tendering stage (based on the vulnerability – robustness parameters and project & firm information), the predicted project cost increase value will be within the +/- 16.6277 % range of the actual value of the forthcoming project.

Average error and error standard deviation for each data set for Model 6 - similarity rule 1 - prediction rule 3 are shown in Fig. 6.14. To sum up, for alternative-3, similarity rules and prediction methods chosen for each model is shown in Figure 6.15.

However, the error rate of Model 6 is nearly twice the error rate of Model 3 (as can be seen from Figures 6.14 and 6.7, respectively). Therefore, it is concluded that alternative-3 is not as feasible and reliable as alternative-1.

After analyzing all the alternatives, it is seen that alternative-1 gives the best results. This also proves the ontology by Fidan (2008) stating that risk and vulnerability parameters actually follow each other and when this is taken into account the reliability of the models improve.

6.3.1.5 Comparing the Projects by not Using ESTEEM

The question is whether ESTEEM is really necessary for assessment of similarities or the same similarity assessment performance can be possible by manual/visual analysis?

In manual/visual analysis, all the projects within the database are compared based on project information and vulnerability – robustness factors that would be known in the tendering stage (beginning of the project) and for all projects the most similar cases are found and their unexpected project cost increases are compared. On the other hand, when ESTEEM is employed, based on the most reliable solution (alternative-1), project cost increase is predicted for each project in the database. Figure 6.16 shows the error rates when projects are compared by hand and when projects are compared through the system.

First two columns in Figure 6.16 shows the most similar projects based on project information and vulnerability robustness factors and third column shows the similarity rating. Fourth and fifth columns give the unexpected cost increase for each respective project and sixth column is the difference amongst them (error rate). Seventh column is the prediction score for the first project when ESTEEM is used and the final column is the difference between the actual cost increase of the first project and the predicted value. As can be seen from this figure, although similarity ratings are more than 80 %, ESTEEM gives a lot better results as compared to ones obtained by hand checking.

Fig 6.16	Similiar Project Couples		Similarity Rate based on Risk Ratings	Unexpected Cost Increase Rate		Error Rate	Prediction Model Score for the 1st Project	
	1st Project	2nd Project		1st Project	2nd Project		Outcome	Error Rate
1st Couple	Project 25	Project 31	87%	20%	5%	(20 - 5) = 15 %	24%	(24 - 20) = 4 %
2nd Couple	Project 40	Project 49	85%	20%	35%	(35 - 20) = 15 %	23%	(23 - 20) = 3 %
3rd Couple	Project 50	Project 31	83%	40%	5%	(40 - 5) = 35 %	25%	(40 - 25) = 15 %
4th Couple	Project 54	Project 58	83%	15%	100%	(100 - 15) = 85 %	18%	(18 - 15) = 3 %
5th Couple	Project 24	Project 26	83%	45%	15%	(45 - 15) = 30 %	31%	(45 - 31) = 14 %

Figure 6.16 Comparison of error rates.

These above-mentioned differences are due to following reasons:

- Importance factors for each parameter are not considered when checking by hand. However, ESTEEM takes this problem into consideration.
- Only one link between vulnerability – robustness factors and project cost increase is considered when projects are checked manually. However, in ESTEEM, three different models are formed and risk paths are created based on the ontology which further increases the reliability.
- Five different prediction rules are considered for each model. When projects are compared by the hand, only the most similar project is taken. However, in ESTEEM 10-15 even 20 most similar projects are considered to get the most optimum solution.
- Beside the three case-based models, a rule base model is also applied to the system to consider the manageability (resilience factors) in the adverse changes. This rule base can increase or decrease the impact of the adverse changes towards the project cost increase.

Due to these factors, using ESTEEM gives more reliable solutions than manual analysis.

Tested Project		Prediction Methods					Error Rate for Each Prediction Method				
	Pr. 28	Most Sim.	10 - ave	10 - mode	20 - ave	20 - mode	Most Sim.	10 - ave	10 - mode	20 - ave	20 - mode
Adverse Changes During Construction Phase	1	1	1	0	1	0	0.00	0.02	0.20	0.09	0.20
	2	1	1	1	2	3	0.20	0.12	0.20	0.00	0.20
	0	3	2	0	2	3	0.60	0.32	0.00	0.38	0.60
	0	0	1	0	1	0	0.00	0.20	0.00	0.21	0.00
	3	2	2	3	2	3	0.20	0.12	0.00	0.12	0.00
	2	3	2	2	2	2	0.20	0.08	0.00	0.06	0.00
	3	3	2	2	2	2	0.00	0.20	0.20	0.21	0.20
	5	2	2	2	2	2	0.60	0.60	0.60	0.58	0.60
	3	4	2	4	2	2	0.20	0.12	0.20	0.12	0.20
	3	4	2	2	2	2	0.20	0.20	0.20	0.19	0.20
	3	4	3	3	2	3	0.20	0.04	0.00	0.12	0.00
	2	3	3	1	2	2	0.20	0.12	0.20	0.09	0.00
	3	3	3	3	3	3	0.00	0.06	0.00	0.06	0.00
	0	1	1	1	2	2	0.20	0.24	0.20	0.36	0.40
	0	1	1	0	1	0	0.20	0.28	0.00	0.24	0.00
	0	2	2	3	2	3	0.40	0.42	0.60	0.49	0.60
	2	3	2	3	2	3	0.20	0.02	0.20	0.03	0.20
	3	3	2	3	2	2	0.00	0.20	0.00	0.13	0.20
		Reliability Rate for Each Prediction Method					**0.80**	**0.81**	**0.84**	**0.81**	**0.80**

Figure 6.17 Results for Model 1 for alternative-1.

6.3.1.6 Model Test Sample

In order to test the models and give a better understanding through demonstration, a project is picked. Test sample project is a 115,000,000 $ building project (shopping mall, hospital etc.) that was built in United Arab Emirates in the year 2006. Data for this project is gathered through a survey that was put into the web beforehand. The name of the project and the name of the contractor firm is unknown. With the data gathered from the web, results for the first model which links the vulnerability – robustness parameters and adverse change factors are shown in Figure 6.17.

In this figure, the left most column gives the original values for the test project. The next five columns give the prediction values for each parameter for every prediction method. On the right side, differences (error rates) for each parameter on every prediction method are given and finally on the right bottom row, reliability rates based on the average of the error for each parameter are calculated. Although prediction method 3 gives the highest reliability value for this project (84 %) for Model 1 it has been proven that prediction rule 2 (average of 10 most similar projects) gives a better result for all the projects. Therefore, results for prediction method 2 (81 % reliability rate) is chosen.

Tested Project		Prediction Methods					Error Rate for Each Prediction Method				
	Pr. 28	Most Sim.	10 - ave	10 - mode	20 - ave	20 - mode	Most Sim.	10 - ave	10 - mode	20 - ave	20 - mode
Risk Events	2	1	1.6	1	1.6	1	0.20	0.08	0.20	0.09	0.20
	3	2	1.9	2	1.8	1	0.20	0.22	0.20	0.25	0.40
	2	1	1.7	2	1.7	2	0.20	0.06	0.00	0.06	0.00
	1	1	1.5	1	1.6	1	0.00	0.10	0.00	0.11	0.00
	2	1	1.5	2	1.6	2	0.20	0.10	0.00	0.09	0.00
	2	1	1.4	1	1.4	1	0.20	0.12	0.20	0.12	0.20
	1	1	1.7	1	1.6	1	0.00	0.14	0.00	0.12	0.00
	1	1	1.8	1	1.5	1	0.00	0.16	0.00	0.10	0.00
		Reliability Rate for Each Prediction Method					0.88	0.88	0.93	0.88	0.90

Figure 6.18 Results for Model 2 for alternative-1.

Tested Project		Prediction Methods					Error Rate for Each Prediction Method				
	Pr. 28	Most Sim.	5 - ave	10 - ave	15 - ave	20 - ave	Most Sim.	5 - ave	10 - ave	15 - ave	20 - ave
% inc.	25	20	17.2	19.9	21.8	23.5	5.00	7.80	5.10	3.20	1.50
		Error Rate for Each Prediction Method					5.00	7.80	5.10	3.20	1.50

Figure 6.19 Results for Model 3 for alternative-1.

After the magnitudes of adverse change parameters are chosen from Model 1, rule base model is applied in order to find the impact of the adverse changes to the project cost increase. Results show that there is 85 % reliability rate for rule base model.

With the impacts found in rule base model, Model 2 is formed. Results are shown in Figure 6.18. On the left side of this figure, original parameters and the predicted values for each factor are given (as in Figure 6.17). On the right side, the differences (error rates) and the reliability ratings are shown. As explained before, the best prediction rule for Model 2 is prediction method 3 which also gives the highest value (93 %).

Link between the risk events found in Model 2 and risk consequence (project cost increase) is Model 3. Results for Model 3 are shown in Figure 6.19.

For the test project, original project cost increase value is 25 %. With the prediction rules of CBR-based RCAT, the calculated value is 23.5 % and the error difference is only 1.5 %. However, for Model 3, the best solution for all the projects is found as prediction method 4 (average of the 15 most similar projects) therefore the predicted value for the system is 21.8 % and the error rate is 3.2 %.

Fig. 6.20	Project Type	Country	Project Cost	Project Duration	Contract Type	Project Delivery System Type	Project Payment Type	Company's Role	Actual Cost Increase	Calculated Cost Increase	Error Rate
Project 1	Buildings	Tajikistan	$75,000,000	15 months	Local Regul.	Turnkey	Lumpsum	Sole Contractor	65%	62%	3%
Project 2	Transportation	Bulgaria	$30,000,000	12 months	Local Regul.	Turnkey	Lump Sum	Sole Contractor	60%	68%	8%
Project 3	Buildings	Rusia	$80,000,000	20 months	FIDIC	Turnkey	Unit Price	Consortium	45%	57%	12%

Figure 6.20 Results for additional test samples for alternative-1.

Besides the building project given as the test sample, three additional samples are tested. Although the details for these three projects are not shown, original project cost increase value, predicted value and the differences (error rate) between them can be seen in Figure 6.20.

It is also worth mentioning the factors that affect the cost increase most, for the three models in alternative-1. According to the findings, these factors are ordered from high to low as shown in Figures 6.21, 6.22 and 6.23 for each model respectively.

In Model 1, vulnerability that affects the project cost increase most is the economic conditions of the country (Co.E), followed by financial situation of the company (Co.F), client (Pr.Cl) and performance of the company (P.Co).

In Model 2, risk source that affects the project cost increase most is change in plan followed by change in scope, change in legal system and change in staff.

In Model 3, risk event that affects the project cost increase most is delay in progress payments (D.in.P.P) followed by increase in quantity of work (I.in.Q.W), delay in site hand-over (D.in.S.H) and delay in logistics (D.in.L).

When system is used in the future and additional projects are added to the system, the error rate of the CBR-based RCAT program will reduce in time and will give more reliable solutions.

Important Factors for Model 1	
C.E	3.84
Co.F	3.73
Pr.Cl	3.65
P.Co	3.52
Co.M	3.44
Co.S	3.38
C.P	3.31
P.D	3.28
Co.T	3.27
Co.E	3.25
P.E	3.20
C.L	3.19
P.M	3.10
Pr.P	3.03
C.M	2.98
Pr.D	2.91
C.S	2.90
P.T	2.89
Pr.C	2.86
P.S	2.54

Fig 6.21 Important Factors for Model 1

Important Factors for Model 2	
Plan	13.08
Scope	9.37
Legal	9.26
Staff	7.26
Design	6.70
Res	4.55
Exter	4.44
Pol	4.24
Cons	3.58
Tech	3.07
P.C	2.99
Econ	2.35
F.R	2.34
Client	1.60
C.B.P	1.24
Des	0.45
Part	0.10
P.R	0.10

Fig. 6.22 Important Factors for Model 2

Important Factors for Model 3	
D.in.P.P	11.56
I.in.Q.W	7.98
D.in.S.H	7.76
D.in.L	6.11
D.in.B	6.03
I.in.U.C	4.98
D.in.Ql.W	4.14
D.in.P	3.75

Fig. 6.23 Important Factors for Model 3

CHAPTER 7

A PRACTICAL APPLICATION FOR JAVA PROGRAM

Details of each case-base model are explained in the previous chapter. Keeping the structure and the working principles, a Java program has been written in order to work with a more user-friendly program which can be used in different computers.

Before the present Java program was written, case-base model simulations in this study are carried out using the ESTEEM 1.4 program (developed in 1991). Unfortunately, this program has only the basic commands, and its output cannot be transferred to other computer programs such as Word and Excel, and each output has to be implemented to the Excel sheet manually one by one. This process not only increases the chances to make mistakes but also requires a long time to get results from the three case-base models and one rule-base model. This makes it especially difficult to make comparisons when parametric studies are made. Therefore, a Java program has been written to allow the use of the case-base models by replacing the commercial program ESTEEM. However all the system's interior structure and formulas are kept the same to be able to get the same results.

The Java program consists of three windows. Figure 7.1 shows the main window that comes up when the program is initiated. The user first writes the name of the project in the "Project Name" box, and saves the project under that name. This helps other users to understand the project from its file name and save time. Then, some general information is asked in two parts. In PART-1, project type, project cost, project duration, contract type, payment type and company's role in the project are asked. Project cost and project durations are the only places where numbers are used as input.

All other answers are chosen from lists. In PART-2, vulnerability–robustness parameters related with country, project, company and other participants involved in the project are gathered. Risk factors are evaluated using 1–very low, 2–low, 3–normal, 4–high and 5–very high risk ratings, as in the ESTEEM program.

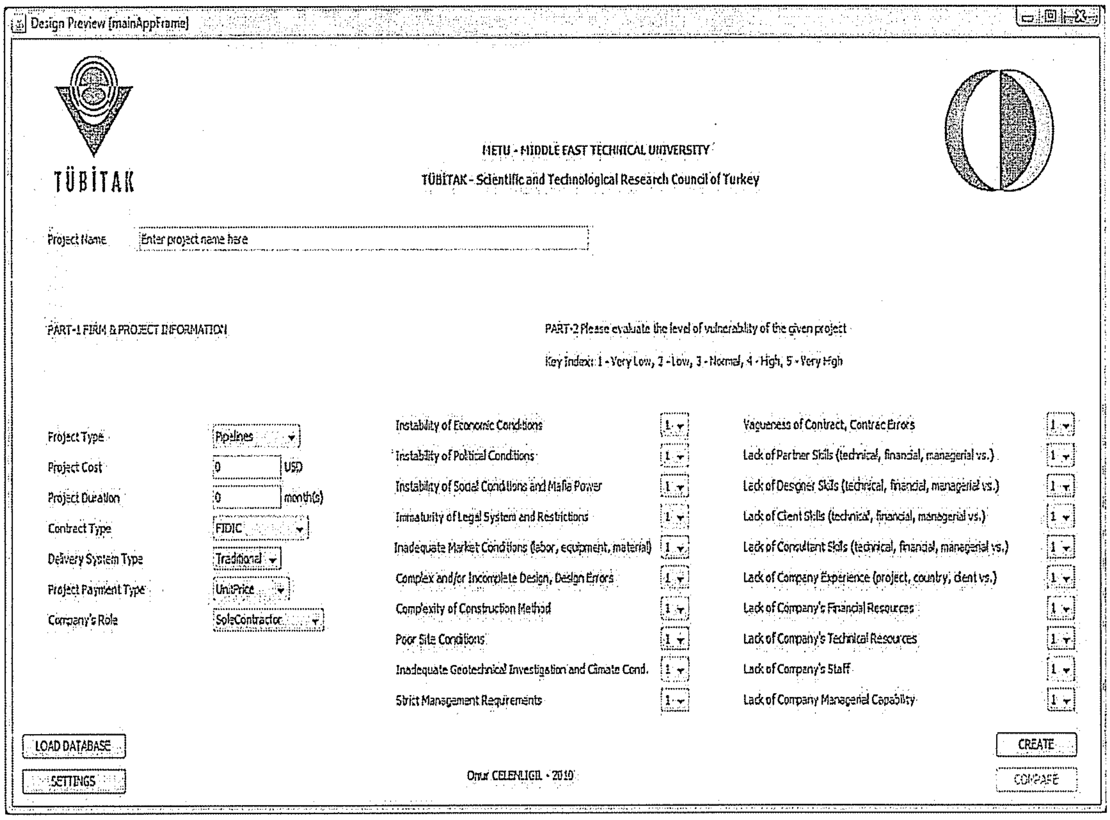


Figure 7.1 Main window for the present Java program.

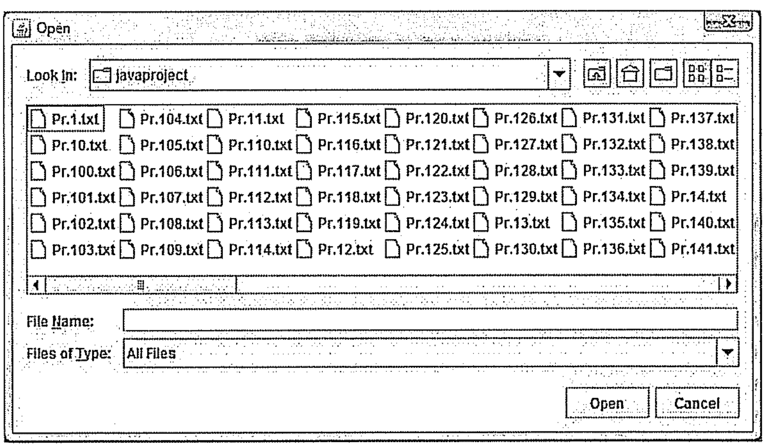


Figure 7.2 Installing the previous projects into the system's database.

After the project name is written and all the input parameters are entered, user presses the "LOAD DATABASE" button to retrieve the previously completed international construction projects to the system's database in order to predict the unexpected project cost for the new project.

Every international construction project has its own unique characteristics. Therefore, the program is designed such that it allows the user to choose either all or some of the projects from the system's database (by excluding the unwanted ones) to be used in the analysis as shown in Figure 7.2.

Then, the "CREATE" button is pressed to start creating the project in the program. After that the "COMPARE" button is pressed to compare the present project with those imported to the system's database. (Note that the "COMPARE" button cannot be activated before the "CREATE" button.)

The Expected Outcomes of the Project are Listed as Below

Magnitude of Adverse Change (deviation from the expected values).		Magnitude of Adverse Change after Manageability	
Economical Conditions in Country	4 - High	Economical Conditions in Country	3 - Normal
Legal System in Country	3 - Normal	Legal System in Country	1 - Very Low
Political View in Country	3 - Normal	Political View in Country	2 - Low
Partner	1 - Very Low	Partner	1 - Very Low
Consultant	3 - Normal	Consultant	2 - Low
Designer	3 - Normal	Designer	2 - Low
Client	2 - Low	Client	1 - Very Low
Communication Btwn Parties	3 - Normal	Communication Btwn Parties	3 - Normal
Scope	3 - Normal	Scope	3 - Normal
Design	2 - Low	Design	1 - Very Low
Construction Technology Method	3 - Normal	Construction Technology Method	2 - Low
Plan	3 - Normal	Plan	3 - Normal
Staff	3 - Normal	Staff	3 - Normal
Resources	3 - Normal	Resources	3 - Normal
Public Relations	3 - Normal	Public Relations	3 - Normal
External Factors	3 - Normal	External Factors	3 - Normal
Financial Resources	2 - Low	Financial Resources	2 - Low
Performance of Contractor	3 - Normal	Performance of Contractor	2 - Low

Impacts of Unexpected Events on the Project Cost		Magnitude of the Risk Events and Impact on the Project Cost	
Social unrest/disorder	0 - None	Decrease in Productivity	3 - Normal
War/Hostilities	0 - None	Increase in Quantity of Work	2 - Low
Rebellion/Terrorism	0 - None	Decrease in Quality of Work	2 - Low
Natural Catastrophes	0 - None	Increase in Unit Cost of Resources	2 - Low
Historical Findings	0 - None	Delay in Bureucracy	2 - Low
Accidents	1 - Very Low	Delay in Site Hand-over	3 - Normal
Damage to Site	0 - None	Delay in Logistics	3 - Normal

Figure 7.3 Second window in the Java program (Predicted Project Scores).

As mentioned before, in alternative-1, three case-base models are formed in the ESTEEM program. In Model 1, all the parameters have equal importance weights, and average of the 10 most similar projects is taken to find the magnitude of the adverse changes. In the Model 2, experts have determined the importance weight for each parameter, and mode of the 10 most similar projects is used in order to find risk events. In the Model 3, importance weight for each parameter is chosen to be same (as in the Model 1), and average of the 15 similar project is taken to find the unexpected project cost increase. Java program gives results based on the same structure and formulas for each model. Figure 7.4 shows the predicted project scores for project 162 that is used to test the Java program. For project 162, actual value for the project cost increase is 40 % and the Java program gives 45%.

The user has two options after the use of the Java program and finding the results for the project. To save the project, the "SAVE PROJECT" button is used and program saves the details of the project under the name written in project name slot. Saved project is in WordPad format and user can later make changes in it. This way if the project has any major changes rather than what was predicted in the tendering stage user will be allowed get inside the project and make those changes. Moreover, when the project is saved in the database, it may be used to make predictions for the future projects. This way program will be enhanced whenever new projects are saved in the system's database and its reliability will increase. If the user does not want to save the project in the system's database or wants to make a few adjustments before saving, the "QUIT WITHOUT SAVE" button can be pressed.

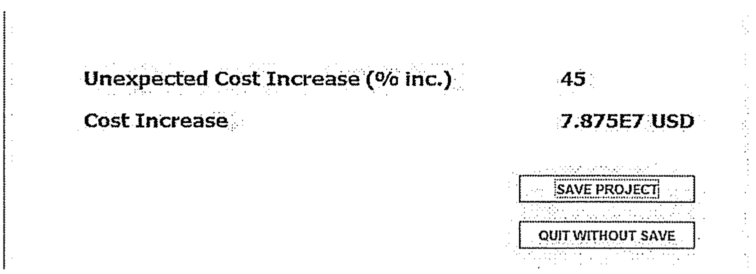


Figure 7.4 Third window in the Java program (unexpected project cost for project 162).

As mentioned previously, 166 projects are already converted into WordPad format in order for the user to predict the project cost increase. However, user does not have to use the format that programmers have made. The user may modify the values for each parameter and even add or remove parameters from the projects. This way each company may adapt the program according to its expertise.

In the previous chapter, the error rate for unexpected project cost comes out to be 8.5642 % for the best alternative (alternative-1). With the Java program, the error rate is decreased to 7.15 %. The reason why the Java program has a smaller error rate is that in ESTEEM, all projects are divided into 5 equal sets and every time one set is designated to be the test sample in order to calculate the error rates. However, when the Java program is used, it is already known that the best solution is alternative-1 and the error rate is between acceptable values therefore there is no need to divide the projects into five data sets and test each time again. Consequently, Java program has much more projects in its database and there are more projects for comparison, and this increases its accuracy.

As emphasized in the previous paragraphs, Java program maintains the similarity rules and prediction methods for every model in order to give the best result. However, if the user wishes, he/she can adjust the importance weights or change the prediction rules (either by including more projects into consideration or shifting from mode to average or visa versa) by clinking on the "SETTINGS" button from the first window.

As seen in Figure 7.5, when the user enters the "SETTINGS" menu, all importance factors and prediction rules that are used in ESTEEM pop up by default. User can play with the numbers in importance factors and/or change the number of projects involved in the prediction method for each model, press the "COMPARE" button to see quick results according to the changes and this way can choose which rule is best for the project. After the best rules for each model is chosen, the results can be saved and, in the future when other projects come, comparisons can be made with the previously saved projects.

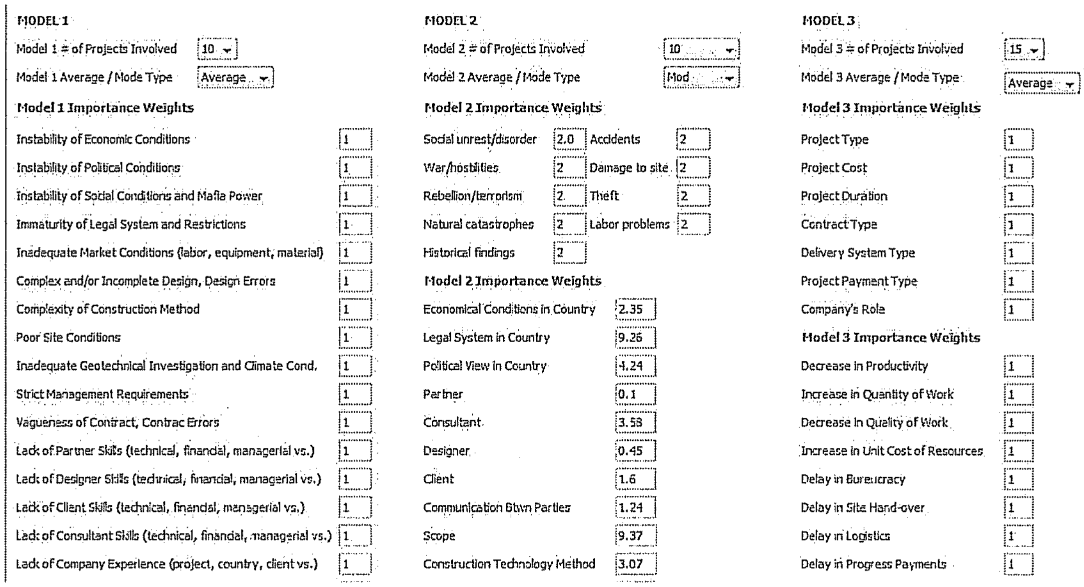


Figure 7.5 Settings menu where the similarity rule and prediction model can be changed.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

This chapter finalizes the findings of the study by concluding the results of the models, pointing out the substantial parts, pros and cons of the study and recommendations for further researches.

This study has three main goals:

- Testing the ontology framework for risk and vulnerability parameters which Fidan (2008) has created in international construction projects. Proving that the risk parameters follow a "risk path" in construction and should not be considered at the same time.
- After figuring out which models suit the international construction projects, carrying out the study by building a case-based reasoning program that predicts the project cost increase by examining the risks and vulnerabilities throughout the project.
- After building the structure of the program, building a user-friendly Java program that allows everyone to use the program without requiring other commercial programs.

In order to achieve these goals, entire work is divided into two categories: gathering necessary projects by conducting surveys, and developing/testing the models created by programs.

Conducting surveys take considerable amount of time because visits to construction companies are made not only in Ankara but also in Istanbul. This thesis is performed at METU in Ankara, and no difficulties are encountered in conducting surveys with the experts who have international experience, working for companies located in Ankara. However, some difficulties are encountered in getting feedback from companies in

Istanbul and it is difficult to get in touch with them because of the long distance. Careful planning and organization are needed to conduct surveys with them.

In order to link the vulnerability and risk parameters to each other, long surveys are prepared but this results in receiving few faultless response. Moreover, each survey takes about 30-45 minutes for a project, and this results in concentration loss for the survey participants and inevitably can lead to mistakes and misunderstandings. For the future researches, more brief surveys are recommended in order to receive better feedbacks.

After the surveys are completed, models are created with ESTEEM. However, as mentioned in Chapter 4, there were too many parameters to link the vulnerability and risk factors considering the number of the real cases. Therefore, hypothetical cases are created alongside with categorizing the parameters by grouping. Creating the hypothetical cases and adjusting the models for broader parameters has taken two months to be completed. This points out the importance of conducting briefer surveys.

After the surveys are finalized and hypothetical cases are proven to be useful for the projects, models are tested one by one to get the optimum solution. At the end, models show that there is only 7.15% error rate for predicting the project cost increase by checking vulnerability and risk parameters. In other words, if this program is used in the future, when the companies would like to see the predicted outcome of the project at tendering stage, program will scan all the projects saved in its database, find out the give a possible project cost increase with only 7.15% error rate. The reason why the performance error rate is somewhat higher than the potential reliability rate of the Java program is that the boundary cases (the projects with close to 0% and 100% project cost increases) have fewer similar cases than the other projects. Therefore, when the program is trying to find prediction scores for projects close to 0% cost increase, predictions with 10-15% cost increases are made. Similarly, when predictions are made for projects with 100% cost increase, outcomes come out to be as 85%. These differences in the prediction error rates of the boundary cases are higher than the mean value error rates, and this influences the error calculations.

This program works as a case-based reasoning program. In other words, it will enhance itself continuously as new projects are saved into its database. With each new project, program will have additional case to find similarity, and thus, give a better result for future projects. Moreover, in contrast to rule-based reasoning or artificial neural network, case-base reasoning (CBR) takes experience and gut feelings into account as well and does not just try to find a mathematical formula for each vulnerability and risk factor.

Experience is one of the most important assets in international construction fields. When a person steps forward to take responsibility (by becoming an engineer, manager, *etc.*) in a project, it will take some time to fully master the position. Mistakes may be made and some of these mistakes might even cause money, time or reputation losses for the company, but experience is gained in the meantime. However, when this person leaves the company (by resigning, retiring, *etc.*), all the experience and gut feeling of this person goes away with him as well. The new person in the job, may need some time to get fully experienced and will probably make the same mistakes during this period, like the previous employee. In order to break this vicious circle, experience needs to be shared with others. CBR may be used for that because every time a new project is completed, experience and results are saved in the system's database which decreases the chance to make the same mistakes in the future substantially.

Sharing experience is precious not only within the company but also among other contractors. Very few Turkish construction companies are inside the top 100 construction firms in the world, and even fewer enhance themselves systematically. Interaction and experience sharing among them need to be improved. In order to put long-established companies into better spots and helping the newly-established companies going abroad for the first time, the CBR program developed in this thesis might not give advise for each step they have to take, however it can help them to have an idea on what might go wrong in a project.

In order to increase usability of this system, Java program has been written. This way, without any commercial program or a good knowledge of computer usage, predictions can be made by only "double-clicking" the program. With easy-follow ups, a first-time user can easily navigate throughout the program for his own purpose.

Every construction project has its own important features. The newly-built Java program allows users to include additional features, such as removing old information and modifying importance weights to improve results. Moreover, users may also use their own projects alone and exclude the others.

This study is a part of an ongoing research project which aims to develop a multi-agent system for risk management of construction projects. Vulnerability and risk features are held according to the ontology of Fidan (2008) that is served for development of a knowledge base system. With the designed ontology, risk impacts are quantified and project cost increase is determined for each project. Intelligent agents that negotiate to quantify the final impact of risks on each party form the basis of a multi-agent platform. During negotiations, intelligent agents obtain required information for problem-solving and decision-making from the developed database. Created models not only serve the multi-agent platform with the project cost increase that will trigger the negotiation, but also give insight on which features trigger the project cost increase, and this forms the way on how the negotiation take place as well.

Although the present program can be used for any project type, future studies need to be done on more specific fields (such as building types, energy, coastal structure, *etc.*). This way, with enough projects saved into the database, results could become more accurate and construction companies related with the specific field can use the program without needing to add/remove or change features.

Despite having a total of 166 projects saved into its database results can be improved further by adding additional cases. For future researches, additional time can be spared for data collection which can eliminate the necessity of using hypothetical cases.

REFERENCES

Aamodt, A. and Plaza, E. (1994), "Case-based reasoning: foundational issues, methodological variations, and system approaches", AI Communications, IOS Press, Vol. 7, No. 1, pp. 39-59.

Arditi, D. and Tokdemir, O. B. (1999), "Comparison of case-based reasoning and artificial neural networks", Journal of Computing in Civil Engineering, 13(3), pp. 162-169.

Roddis, W.M.K. and Bocox, J.C. (1997), "Case-based approach for steel bridge fabrication errors", Journal of Computing in Civil Engineering, Vol. 11, No. 2, pp. 84-91.

Chen, D. and Burrell, P. (2001), "Case-based reasoning system and artificial neural networks: A review", Neural Comput. Appl., 10(3), pp. 264-276.

Chen, J.H., Yang, L.R., Chen, W.H. and Chang, C.K. (2008), "Case-based allocation of onsite supervisory manpower for construction projects", Construction Management and Economics, 26(8), pp. 805-814.

Chua, D.K.H., Li, D.Z. and Chan, W.T. (2001), "Case-based reasoning approach in bid decision making", Journal of Construction Engineering and Management, 127(1), pp. 35-45.

Chua, D.K.H., and Loh, P.K. (2006), "CB-contract: case-based reasoning approach to construction contract strategy formulation", in Journal of Computing in Civil Engineering, ASCE2006, pp. 339-350.

Deng, P.S (1994), "Using case-based reasoning for decision support", Proceedings of the twenty-seventh annual Hawaii international conference on system sciences, pp. 552-560.

Dikmen, İ., Birgönül, M.T. and Gür, A.K. (2007), "A case-based decision support tool for bid mark-up estimation of international construction projects", Automation in Construction, 17, pp. 30-44.

Dzeng, R. J., and Tommelein, I. D. (1997), "Boiler erection scheduling using product models and case-based reasoning", J. Constr. Eng. Manage., 123(3), pp. 338-347.

Fidan, G. (2008), "A risk and vulnerability ontology for construction projects", M.S. Thesis, METU.

Hammond, K.J. (1989), "Case-based planning", Academic Press.

Hennessy, D. and Hinkle, D. (1992), "Applying case-based reasoning to autoclave loading", IEEE Expert 7(5), pp. 21-26.

Hinrichs T.R. (1992), "Problem solving in open worlds", Lawrence Erlbaum Associates.

Kolodner, J. (1983), "Reconstructive memory, a computer model", Cognitive Science, Vol.7, pp. 281-328.

Koton P. (1989), "Using experience in learning and problem solving", Massachusetts Institute of Technology, Laboratory of Computer Science (Ph.D. diss, October 1988), MIT/LCS/TR-441.

Lee, C.H.L. and Liu, A. (2005), "A CBR-BDI agent for service access enhancement in ATIS", International Journal of Fuzzy Systems, 7(2), pp. 76-84.

Lee, C.H.L., Liu, A. and Chen, K.Y. (2003), "An agent-based software development method for developing an agent-based multimedia system", in Proc. IEEE MSE2003, pp. 132-139.

Li, H. (1996), "Selecting KBES development techniques for applications in construction industry", Constr. Manage. Econom., 14(1), pp. 67-74.

Li, H. (1996), "Case-based reasoning for intelligent support of construction negotiation", Information and management, 30, pp. 231-238.

Liu, M. and Ling, Y.Y. (2005), "Modeling a contractor's markup estimation", ASCE Journal of Construction Engineering and Management, 131(4), pp. 391-399.

Luu, D.T., Ng, S.T. and Chen, S.E. (2005), "Formulating procurement selection criteria through case-based reasoning approach", Journal of Computing in Civil Engineering, ASCE2005, pp. 269-276.

Naderpajouh, N. and Afshar, A. (2008), "A case-based reasoning approach to application of value engineering methodology in the construction industry", Construction Management and Economics, 26(4), pp. 363-372.

Ng, S.T. (2001), "EQUAL: a case-based contractor prequalifie", Automation in Construction, 10, pp. 443-457.

Ozorhon, B., Dikmen I. and Birgonul M.T. (2006), "Case-based reasoning model for international market selection", Journal of Construction Engineering and Management, ASCE2006, pp. 940-948.

Perera, S. and Watson, I. (1998), "Collaborative case-based estimating and design", Adv. Eng. Software, 29(10), pp. 801-808.

Rich, E. and Knight, K. (1991) "Artificial intelligence", 2nd Ed., McGraw-Hill, New York, N.Y.

Schmitt, G. (1993), "Case-based design and creativity", Automation in Construction, 2, pp. 11-19.

Simpson, R.L. (1985), "A computer model of case-based reasoning in problem solving: An investigation in the domain of dispute mediation", Technical Report GIT-ICS-85/18, Georgia Institute of Technology.

Sycara, K. (1988), "Using case-based reasoning for plan adaptation and repair", Proceedings Case-Based Reasoning Workshop, DARPA, Clearwater Beach, Florida, Morgan Kaufmann, pp. 425-434.

Sycara, K. and Miyashita, K. (1994), "Learning from failure experiences in case-based schedule repair", Proceedings of the twenty-seventh annual Hawaii international conference on system sciences, pp. 122-131.

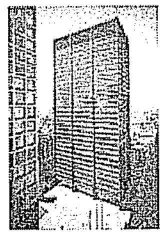
Tah, J. H. M., Carr, V. and Howes, R. (1999), "Information modeling for case-based construction planning of highway bridge projects", Adv. Eng. Software, 30(7), pp. 495-509.

Yau, N. J., and Yang, J. B. (1998), "Case-based reasoning in construction management", Comput. Aided Civ. Infrastruct. Eng., 13(2), pp. 143-150.

APPENDIX A

SAMPLE QUESTIONNAIRE

PART 1: FIRM & PROJECT INFORMATION



1	Project Type:	☐ Pipelines (petroleum, natural gas) ☐ Industrial Plants (chemical, refinery) ☐ Infrastructure ☐ Transportation ☐ Buildings (shopping malls, hospitals etc.) ☐ Dams ☐ Housing ☐ Energy (nuclear,hydroelectric plants) ☐ Coastal Structures (harbor, breakwater) ☐ Other, please specify...
2	Total project cost (original contract value)	____________________ USD
3	Project duration	____________________ Months
4	Contract type	☐ FIDIC ☐ Local Regulations
5	Project delivery system type	☐ Traditional (design-bid-build) ☐ Turnkey (design-build) ☐ Other, please specify...
6	Project payment type	☐ Unit Price ☐ Lump Sum ☐ Cost + Fee ☐ Other, please specify...
7	Company's role in the project	☐ Sole Contractor ☐ Joint Venture Partner ☐ Consortium Partner ☐ Subcontractor ☐ Other, please specify...

Figure 9.1 Sample Questionnaire Part 1

A. Following are some vulnerability factors that have a potential to create risks. Please rate the POTENTIAL OF THESE FACTORS TO CREATE RISKS in the international construction environment.
You are kindly required to evaluate these factors in GENERAL (not for your preoject but for all possible projects in international markets) Please fill this section only ONCE.

No	Groups		Items	Very Low	Low	Medium	High	Very High
1	Country related	Economic	Instability of economic conditions					
2	Country related	Political	Instability of government					
3	Country related	Political	Instability of international relations					
4	Country related	Political	Level of bureaucracy					
5	Country related	Social	Level of bribery					
6	Country related	Social	Level of mafia power					
7	Country related	Social	Instability of social conditions					
8	Country related	Legal	Immaturity of legal system					
9	Country related	Legal	Restrictions for foreign companies					
10	Country related	Market	Unavailability of material					
11	Country related	Market	Unavailability of equipment					
12	Country related	Market	Unavailability of labor					
13	Country related	Market	Unavailability of subcontractor					
14	Country related	Market	Unavailability of infrastructure					
15	Project related	Design	Complexity of design					
16	Project related	Design	Incomplete design					
17	Project related	Design	Low constructability					
18	Project related	Design	Design errors					
19	Project related	Construction	Complexity of construction method					
20	Project related	Construction	Poor accessibility of site					
21	Project related	External	Inadequate geotechnical investigation					
22	Project related	External	Inadequate climate conditions					
23	Project related	Management	Strict quality management requirements					
24	Project related	Management	Strict enviromental management requirements					
25	Project related	Management	Strict health&safety management requirements					
26	Project related	Management	Strict project management requirements					
27	Project related	Contract	Vagueness of contract clauses					
28	Project related	Contract	Contract errors					

Figure 9.2 Sample Questionnaire Part A-1

TUBITAK

METU - Middle East Technical University

TUBITAK - Scientific and Technological Research Council of Turkey

A. Following are some vulnerability factors that have a potential to create risks. Please rate the POTENTIAL OF THESE FACTORS TO CREATE RISKS in the international construction environment.
You are kindly required to evaluate these factors in GENERAL (not for your preoject but for all possible projects in international markets) Please fill this section only ONCE.

No	Groups		Items	Very Low	Low	Medium	High	Very High
29	Project participant related	Partner	Technical incompetency					
30			Managerial incompetency					
31			Lack of financial resources					
32			Cultural differences with the company/contractor					
33		Designer	Technical incompetency					
34			Managerial incompetency					
35			Lack of financial resources					
36			Cultural differences with the company/contractor					
37		Consultant/ Engineer	Technical incompetency					
38			Managerial incompetency					
39			Lack of financial resources					
40			Cultural differences with the company/contractor					
41		Client	Unclarity of objectives					
42			Level of bureaucracy					
43			Negative attitude					
44			Poor staff profile					
45			Unavailability of financial resources					
46			Technical incompetency					
47			Poor managerial/organizational ability					
48	Company related	Company Experience	Lack of experience in similar projects					
49			Lack of experience in country					
50			Lack of experience in project delivery system					
51			Lack of experience with client					
52			Lack of experience with partner					
53		Company Resources	Lack of financial resources					
54			Lack of technical resources					
55			Lack of staff					
56		Company Managerial Capability	Lack of project scope management					
57			Lack of project time management					
58			Lack of project cost management					
59			Lack of project quality management					
60			Lack of project human resource management					
61			Lack of project communications management					
62			Lack of project risk management					
63			Lack of project procurement management					

Figure 9.3 Sample Questionnaire Part A-2

TUBITAK

METU - Middle East Technical University

TUBITAK - Scientific and Technological Research Council of Turkey

B.1. IN THIS PART, PLEASE CONSIDER THE CONDITIONS OF YOUR SPECIFIC PROJECT. Please evaluate the MAGNITUDE OF THE FOLLOWING FACTORS considering the bid preparation stage of your project.

No	Groups		Items	Very Low	Low	Medium	High	Very High
1	Country related	Economic	Instability of economic conditions					
2		Political	Instability of government					
3			Instability of international relations					
4			Level of bureaucracy					
5		Social	Level of bribery					
6			Level of mafia power					
7			Instability of social conditions					
8		Legal	Immaturity of legal system					
9			Restrictions for foreign companies					
10		Market	Unavailability of material					
11			Unavailability of equipment					
12			Unavailability of labor					
13			Unavailability of subcontractor					
14			Unavailability of infrastructure					
15	Project related	Design	Complexity of design					
16			Incomplete design					
17			Low constructability					
18			Design errors					
19		Construction	Complexity of construction method					
20			Poor accessibility of site					
21		External	Inadequate geotechnical investigation					
22			Inadequate climate conditions					
23		Management	Strict quality management requirements					
24			Strict enviromental management requirements					
25			Strict health&safety management requirements					
26			Strict project management requirements					
27		Contract	Vagueness of contract clauses					
28			Contract errors					

Figure 9.4 Sample Questionnaire Part B.1-2

B.1. IN THIS PART, PLEASE CONSIDER THE CONDITIONS OF YOUR SPECIFIC PROJECT. Please evaluate the MAGNITUDE OF THE FOLLOWING FACTORS considering the bid preparation stage of your project.

No	Groups		Items	Very Low	Low	Medium	High	Very High
29	Project participant related	Partner	Technical incompetency					
30			Managerial incompetency					
31			Lack of financial resources					
32			Cultural differences with the company/contractor					
33		Designer	Technical incompetency					
34			Managerial incompetency					
35			Lack of financial resources					
36			Cultural differences with the company/contractor					
37		Consultant/ Engineer	Technical incompetency					
38			Managerial incompetency					
39			Lack of financial resources					
40			Cultural differences with the company/contractor					
41		Client	Unclarity of objectives					
42			Level of bureaucracy					
43			Negative attitude					
44			Poor staff profile					
45			Unavailability of financial resources					
46			Technical incompetency					
47			Poor managerial/organizational ability					
48	Company related	Company Experience	Lack of experience in similar projects					
49			Lack of experience in country					
50			Lack of experience in project delivery system					
51			Lack of experience with client					
52			Lack of experience with partner					
53		Company Resources	Lack of financial resources					
54			Lack of technical resources					
55			Lack of staff					
56		Company Managerial Capability	Lack of project scope management					
57			Lack of project time management					
58			Lack of project cost management					
59			Lack of project quality management					
60			Lack of project human resource management					
61			Lack of project communications management					
62			Lack of project risk management					
63			Lack of project procurement management					

Figure 9.5 Sample Questionnaire Part B.1-2

B2. Please indicate whether there is any adverse change in the initial conditions. (If there is no change please indicate it as N/A) Please rate the magnitude of change (deviation from the expected values).						
Adverse change in...	N/A	Very Low	Low	Medium	High	Very High
Currency rates						
Inflation						
Tax rates						
Laws and regulations						
Relations with the government						
Relations with the partner						
Relations with the engineer						
Relations with the designer						
Relations with the client						
Communication between parties						
Performance of the partner						
Performance of the designer						
Performance of the engineer						
Scope						
Design						
Construction technology/method						
Client's staff						
Original schedule/sequence						
Site organization						
Project team (project manager, technical office members)						
Top management (company)						
Availability of labor						
Availability of material						
Availability of equipment						
Availability of subcontractor						
Public reaction						
Atitude of client						
Weather conditions						
Geological conditions						
Site conditions						
Work quality						
Financial situation of the client						
Financial situation of company						
Financial situation of the partner						
Performance of contractor						

Figure 9.6 Sample Questionnaire Part B.2-1

B.2.2. Please indicate the manageability level of the change						
Adverse change in...	N/A	Very Low	Low	Medium	High	Very High
Currency rates						
Inflation						
Tax rates						
Laws and regulations						
Relations with the government						
Relations with the partner						
Relations with the engineer						
Relations with the designer						
Relations with the client						
Communication between parties						
Performance of the partner						
Performance of the designer						
Performance of the engineer						
Scope						
Design						
Construction technology/method						
Client's staff						
Original schedule/sequence						
Site organization						
Project team (project manager, technical office members)						
Top management (company)						
Availability of labor						
Availability of material						
Availability of equipment						
Availability of subcontractor						
Public reaction						
Atitude of client						
Weather conditions						
Geological conditions						
Site conditions						
Work quality						
Financial situation of the client						
Financial situation of company						
Financial situation of the partner						
Performance of contractor						

Figure 9.7 Sample Questionnaire Part B.2-2

B2.3. Please rate the overall impact/consequence of the "change" on the project cost after you managed the revelant risk factor.

Adverse change in...	N/A	Very Low	Low	Medium	High	Very High
Currency rates						
Inflation						
Tax rates						
Laws and regulations						
Relations with the government						
Relations with the partner						
Relations with the engineer						
Relations with the designer						
Relations with the client						
Communication between parties						
Performance of the partner						
Performance of the designer						
Performance of the engineer						
Scope						
Design						
Construction technology/method						
Client's staff						
Original schedule/sequence						
Site organization						
Project team (project manager, technical office members)						
Top management (company)						
Availability of labor						
Availability of material						
Availability of equipment						
Availability of subcontractor						
Public reaction						
Atitude of client						
Weather conditions						
Geological conditions						
Site conditions						
Work quality						
Financial situation of the client						
Financial situation of company						
Financial situation of the partner						
Performance of contractor						

Figure 9.8 Sample Questionnaire Part B.2-3

B.3. Please indicate whether any one of the following unexpected items occured or not.						
Please rate the overall impact/consequence of the unexpected event on the project cost.						
Unexpected events	**N/A**	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Social unrest/disorder						
War/hostilities						
Rebellion/terrorism						
Natural catastrophes						
Historical findings						
Accidents						
Damage to site						
Theft						
Strikes/labor problems						

B.4. Please indicate whether any one of the following risk events occured as a result of adverse change and unexpected event.						
B.4.1. If yes, please rate the "magnitude of the risk events".						
Risk Events	N/A	Very Low	Low	Medium	High	Very High
Decrease in productivity						
Increase in quantity of work						
Decrease in quality of work						
Increase in unit cost of resources						
Delay in bureucracy						
Delay in site hand-over						
Delay in logistics						
Delay in progress payments						

B5. Please indicate the change in the project cost (considering the original value given in the contract):
Cost ____________________ (%)

B6. Please indicate the percentage sharing of change in project cost between project parties. Please keep in mind that the sum must be equal to 100.	
Note: Some of the above listed parties may not be relevant for your project. Please select the parties (you can add more) so that % sharing values add up to 1.	
Note: If negotiations are still going on or your case is waiting for a court decision, please indicate the "most likely" sharing scenario	
	% Sharing of the cost overrun between the parties
Your company-contractor	
JV/consortium partner(s)	
Client	

Figure 9.9 Sample Questionnaire Part B.3

APPENDIX B

SIMILARITY MODELS AND DETAILS ON PROJECTS THAT ARE FOUND SIMILAR FOR PROJECT 28

Abbreviations and Respective Explanations:			
Alt 1	The parameters of the most similar project are taken	**S.1**	The parameters of the most similar project are taken
Alt 2	Average of the 10 most similiar projects are taken	**S.2**	Average of the 5 most similiar projects are taken
Alt 3	Mode of the 10 most similiar projects are taken	**S.3**	Average of the 10 most similiar projects are taken
Alt 4	Average of the 20 most similiar projects are taken	**S.4**	Average of the 15 most similiar projects are taken
Alt 5	Mode of the 20 most similiar projects are taken	**S.5**	Average of the 20 most similiar projects are taken
R.R	Reliability Rate (deviation gets lower as the values gets closer to 0)		

Figure 9.10 Abbreviations and Respective Explanations

Similarity Models And Details On Projects That Are Found Similar (With Real Cases Only)			Values of Similar Projects																				Prediction Models and Respective Reliability Rates	Alt 1		Alt 2		Alt 3		Alt 4		Alt 5	
Model 1	Parameters	Project 28	30	54	4	14	37	6	15	61	62	16	20	44	29	52	57	59	60	65	5	17	Found	R.R	Found	R.R	Found	R.R	Found	R.R	Found	R.R
	Econ	1	0	3	0	0	0	1	2	0	0	3	3	1	0	3	4	3	0	3	0	3	0,0	0,2	0,9	0,0	0,0	0,2	1,5	0,1	0,0	0,2
	Legal	2	1	2	3	2	0	1	1	0	3	2	4	0	3	3	0	0	0	1	0	3	1,0	0,2	1,5	0,1	1,0	0,2	1,5	0,1	0,0	0,4
	Pol	0	0	3	4	3	0	1	0	0	3	2	3	0	3	2	2	0	0	2	0	4	0,0	0,0	1,6	0,3	0,0	0,0	1,6	0,3	0,0	0,0
	Part	0	0	2	2	2	0	0	2	1	1	3	2	0	0	1	1	0	2	3	0	0	0,0	0,0	1,3	0,3	2,0	0,4	1,1	0,2	0,0	0,0
	Cons	3	3	3	3	2	4	1	3	1	1	0	2	0	3	4	1	1	1	2	0	3	3,0	0,0	2,1	0,2	3,0	0,0	1,9	0,2	3,0	0,0
	Des	2	0	2	1	2	0	1	2	2	2	2	0	2	1	2	1	3	2	2	0	0	0,0	0,4	1,4	0,1	2,0	0,0	1,4	0,1	2,0	0,0
	Client	3	4	2	2	2	2	0	2	1	1	2	0	1	0	3	0	3	1	2	0	1	4,0	0,2	1,8	0,2	2,0	0,2	1,5	0,3	2,0	0,2
	C.B.P	5	4	2	1	2	3	1	1	2	2	2	1	2	1	5	0	3	2	3	0	3	4,0	0,2	2,0	0,6	2,0	0,6	2,0	0,6	2,0	0,6
	Scope	3	4	2	3	2	4	0	3	0	0	2	3	2	4	2	0	2	0	2	0	3	4,0	0,2	2,0	0,2	2,0	0,2	1,9	0,2	2,0	0,2
	Design	3	4	2	2	2	0	0	2	2	1	3	4	2	0	2	3	4	2	3	0	3	4,0	0,2	1,8	0,2	2,0	0,2	2,1	0,2	2,0	0,2
	Tech	3	3	3	3	2	4	2	3	1	1	2	0	0	0	3	3	1	1	1	0	0	3,0	0,0	2,4	0,1	3,0	0,0	1,7	0,3	3,0	0,0
	Plan	2	5	4	2	1	4	1	3	1	1	4	3	2	0	3	1	2	3	4	0	3	5,0	0,6	2,6	0,1	1,0	0,2	2,4	0,1	1,0	0,2
	Staff	3	4	3	4	3	0	2	4	1	1	2	1	3	4	3	0	3	1	2	2	0	4,0	0,2	2,4	0,1	4,0	0,2	2,2	0,2	3,0	0,0
	Res	0	0	2	2	2	0	1	2	1	2	2	4	1	2	3	4	3	1	2	2	0	0,0	0,0	1,4	0,3	2,0	0,4	1,8	0,4	2,0	0,4
	P.R	0	0	3	3	2	0	0	0	1	1	0	0	0	0	0	0	2	1	1	0	0	0,0	0,0	1,0	0,2	0,0	0,0	0,7	0,1	0,0	0,0
	Exter	0	3	3	0	1	4	1	3	1	2	3	4	0	0	3	4	1	1	2	1	1	3,0	0,6	2,1	0,4	3,0	0,6	1,9	0,4	1,0	0,2
	F.R	2	3	3	2	2	0	2	3	2	1	1	3	1	0	0	3	2	2	3	2	3	3,0	0,2	1,9	0,0	2,0	0,0	1,9	0,0	3,0	0,2
	P.C	3	0	2	3	2	0	0	5	2	2	2	4	0	4	4	0	2	1	3	0	3	0,0	0,6	1,8	0,2	2,0	0,2	2,0	0,2	0,0	0,6
Model 2	Parameters	Project 28	Values of Similar Projects																				Alt 1		Alt 2		Alt 3		Alt 4		Alt 5	
			20	60	15	64	49	62	57	17	32	37	45	61	65	39	42	59	24	56	1	4	Found	R.R	Found	R.R	Found	R.R	Found	R.R	Found	R.R
	D.in.P	2	3	1	3	2	2	1	2	2	2	2	3	1	2	2	1	2	1	0	3	2	3,0	0,2	3,0	0,2	3,0	0,2	2,9	0,2	3,0	0,2
	I.in.Q.W	3	4	1	3	1	3	1	2	2	3	3	1	1	2	2	0	2	0	0	1	2	4,0	0,2	3,3	0,1	3,0	0,0	2,7	0,1	2,0	0,2
	D.in.Q.W	2	2	1	4	2	2	1	1	2	2	2	3	1	2	2	1	2	0	0	2	3	2,0	0,0	2,9	0,2	4,0	0,4	2,8	0,2	3,0	0,2
	I.in.U.C	1	3	1	2	2	1	1	5	1	1	0	2	1	2	2	1	3	3	1	0	1	3,0	0,4	2,7	0,3	2,0	0,2	2,7	0,3	2,0	0,2
	D.in.B	2	2	0	1	2	1	3	1	3	1	1	3	0	1	2	0	1	3	0	2	3	2,0	0,0	2,5	0,1	1,0	0,2	2,5	0,1	2,0	0,0
	D.in.S.H	2	2	2	3	1	3	1	1	2	2	3	4	1	2	3	2	1	3	1	4	2	2,0	0,0	3,0	0,2	3,0	0,2	3,2	0,2	3,0	0,2
	D.in.L	1	4	1	1	2	1	2	3	2	0	0	2	1	2	2	0	2	3	0	1	3	4,0	0,6	2,6	0,3	1,0	0,0	2,6	0,3	3,0	0,4
	D.in.P.P	1	3	3	3	1	4	1	1	3	2	4	4	1	3	4	4	1	5	2	3	2	3,0	0,4	3,5	0,5	3,0	0,4	3,7	0,5	4,0	0,6
M3	Parameters	Project 28	Values of Similar Projects																				S.1		S.2		S.3		S.4		S.5	
			15	59	46	2	62	65	47	39	41	32	11	17	49	51	66	37	61	19	20	44	Found	Error	Found	Error	Found	Error	Found	Error	Found	Error
	Increase %	25	40	20	215	25	20	20	10	40	65	20	10	25	35	30	20	35	10	15	65	5	40	15	64,6	39,6	47	22	39	14	40	15

Abbreviations and Respective Explanations:			
Alt 1	The parameters of the most similar project are taken	S.1	The parameters of the most similar project are tal
Alt 2	Average of the 10 most similiar projects are taken	S.2	Average of the 5 most similiar projects are taken
Alt 3	Mode of the 10 most similiar projects are taken	S.3	Average of the 10 most similiar projects are taker
Alt 4	Average of the 20 most similiar projects are taken	S.4	Average of the 15 most similiar projects are taker
Alt 5	Mode of the 20 most similiar projects are taken	S.5	Average of the 20 most similiar projects are taker
R.R	Reliability Rate (deviation gets lower as the values gets		

Figure 9.11 Similarity Models And Details On Projects That Are Found Similar (With Real Cases Only)

	Similarity Models And Details On Projects That Are Found Similar (With Real Cases + Hypothetical Cases)																						Prediction Models and Respective Reliability Rates									
	Parameters	Project 28	Values of Similar Projects																				Alt 1		Alt 2		Alt 3		Alt 4		Alt 5	
			69	30	54	90	4	14	37	6	15	61	62	16	20	44	71	94	106	136	29	52	Found	R.R	Found	R.R	Found	R.R	Found	R.R	Found	R.R
Model 1	Econ	1	1	0	3	2	0	0	0	1	2	0	0	3	3	1	1	2	3	4	0	3	1,0	0,0	0,9	0,0	0,0	0,2	1,5	0,1	0,0	0,2
	Legal	2	1	1	2	3	3	2	0	1	1	0	3	2	4	0	3	3	2	3	3	3	1,0	0,2	1,4	0,1	1,0	0,2	2,0	0,0	3,0	0,2
	Pol	0	3	0	3	2	4	3	0	1	0	0	3	2	3	0	2	2	2	3	3	2	3,0	0,6	1,6	0,3	0,0	0,0	1,9	0,4	3,0	0,6
	Part	0	0	0	2	1	2	2	0	0	2	1	1	3	2	0	1	2	1	0	0	1	0,0	0,0	1,0	0,2	0,0	0,0	1,1	0,2	0,0	0,0
	Cons	3	2	3	3	2	3	2	4	1	3	1	1	0	2	0	3	3	4	4	3	4	2,0	0,2	2,4	0,1	3,0	0,0	2,4	0,1	3,0	0,0
	Des	2	3	0	2	3	1	2	0	1	2	2	2	2	0	2	2	2	2	3	1	2	3,0	0,2	1,6	0,1	2,0	0,0	1,7	0,1	2,0	0,0
	Client	3	3	4	2	2	2	2	2	0	2	1	1	2	0	1	3	3	3	3	0	3	3,0	0,0	2,0	0,2	2,0	0,2	2,0	0,2	2,0	0,2
	C.B.P	5	2	4	2	2	1	2	3	1	1	2	2	2	1	2	2	2	3	2	1	5	2,0	0,6	2,0	0,6	2,0	0,6	2,1	0,6	2,0	0,6
	Scope	3	4	4	2	2	3	2	4	0	3	0	0	2	3	2	2	2	3	4	4	2	4,0	0,2	2,4	0,1	4,0	0,2	2,4	0,1	2,0	0,2
	Design	3	4	4	2	2	2	2	0	0	2	2	1	3	4	2	1	1	3	4	0	2	4,0	0,2	2,0	0,2	2,0	0,2	2,1	0,2	2,0	0,2
	Tech	3	4	3	3	3	3	2	4	2	3	1	1	2	0	0	3	4	3	4	0	3	4,0	0,2	2,8	0,0	3,0	0,0	2,4	0,1	3,0	0,0
	Plan	2	3	5	4	2	2	1	4	1	3	1	1	4	3	2	2	2	4	2	0	3	3,0	0,2	2,6	0,1	1,0	0,2	2,5	0,1	2,0	0,0
	Staff	3	3	4	3	3	4	3	0	2	4	1	1	2	1	3	3	3	4	3	4	3	3,0	0,0	2,7	0,1	3,0	0,0	2,7	0,1	3,0	0,0
	Res	0	1	0	2	1	2	2	0	1	2	1	2	2	4	1	3	3	2	2	2	3	1,0	0,2	1,2	0,2	1,0	0,2	1,8	0,4	2,0	0,4
	P.R	0	1	0	3	4	3	2	0	0	0	1	1	0	0	0	2	2	2	3	0	0	1,0	0,2	1,4	0,3	0,0	0,0	1,2	0,2	0,0	0,0
	Exter	0	2	3	3	3	0	1	4	1	3	1	2	3	4	0	4	5	4	3	0	3	2,0	0,4	2,1	0,4	3,0	0,6	2,5	0,5	3,0	0,6
	F.R	2	3	3	3	1	2	2	0	2	3	2	1	1	3	1	2	3	3	2	0	0	3,0	0,2	2,1	0,0	3,0	0,2	1,9	0,0	3,0	0,2
	P.C	3	3	0	2	3	3	2	0	0	5	2	2	2	4	0	2	2	4	3	4	4	3,0	0,0	2,0	0,2	3,0	0,0	2,4	0,1	2,0	0,2
Model 2	Parameters	Project 28	Values of Similar Projects																				Alt 1		Alt 2		Alt 3		Alt 4		Alt 5	
			140	142	110	92	94	20	60	139	151	69	137	145	27	32	5	79	90	120	164	166	Found	R.R	Found	R.R	Found	R.R	Found	R.R	Found	R.R
	D.in.P	2	1	2	1	2	1	3	1	1	2	2	2	1	1	2	1	1	2	2	2	1	1,0	0,2	1,6	0,1	1,0	0,2	1,6	0,1	1,0	0,2
	I.in.Q.W	3	2	1	2	2	1	4	1	1	2	3	1	3	1	3	0	1	1	3	2	1	2,0	0,2	1,9	0,2	2,0	0,2	1,8	0,3	1,0	0,4
	D.in.Q.W	2	1	2	2	2	2	2	1	1	2	2	2	1	1	2	1	2	2	2	2	2	1,0	0,2	1,7	0,1	2,0	0,0	1,7	0,1	2,0	0,0
	I.in.U.C	1	1	2	1	2	1	3	1	1	2	1	3	2	1	1	1	1	1	2	2	2	1,0	0,0	1,5	0,1	1,0	0,0	1,6	0,1	1,0	0,0
	D.in.B	2	1	2	1	2	2	2	0	1	2	2	2	2	1	1	0	2	2	2	1	3	1,0	0,2	1,5	0,1	2,0	0,0	1,6	0,1	2,0	0,0
	D.in.S.H	2	1	1	1	2	1	2	2	1	1	2	2	1	1	2	1	1	2	1	2	1	1,0	0,2	1,4	0,1	1,0	0,2	1,4	0,1	1,0	0,2
	D.in.L	1	1	2	1	2	1	4	1	1	2	2	2	2	1	0	1	1	2	3	1	2	1,0	0,0	1,7	0,1	1,0	0,0	1,6	0,1	1,0	0,0
	D.in.P.P	1	1	1	1	3	1	3	3	1	1	3	1	1	1	2	0	1	1	1	3	1	1,0	0,0	1,8	0,2	1,0	0,0	1,5	0,1	1,0	0,0
M3	Parameters	Project 28	Values of Similar Projects																				S.1		S.2		S.3		S.4		S.5	
			62	32	112	140	47	134	11	39	145	61	17	90	92	117	59	96	115	120	142	161	Found	Error	Found	Error	Found	Error	Found	Error	Found	Error
	Increase %	25	20	20	20	10	12	30	10	40	25	10	25	15	25	45	20	40	30	30	15	30	20	5	16,4	8,6	19,7	5,3	21,8	3,2	23,6	1,4

Abbreviations and Respective Explanations:			
Alt 1	The parameters of the most similar project are taken	S.1	The parameters of the most similar project are tal
Alt 2	Average of the 10 most similiar projects are taken	S.2	Average of the 5 most similiar projects are taken.
Alt 3	Mode of the 10 most similiar projects are taken	S.3	Average of the 10 most similiar projects are taker
Alt 4	Average of the 20 most similiar projects are taken	S.4	Average of the 15 most similiar projects are taker
Alt 5	Mode of the 20 most similiar projects are taken	S.5	Average of the 20 most similiar projects are taker
R.R	Reliability Rate (deviation gets lower as the values gets		

Figure 9.12 Similarity Models And Details On Projects That Are Found Similar (With Real Cases + Hypothetical Cases)