RISK ANALYSIS AND MANAGEMENT OF CONSTRUCTION PROJECTS TENDERED UNDER DESIGN-BUILD (TURNKEY) CONTRACT SYSTEM

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To

My Parents, Sevgi ÖKMEN

&

Faik ÖKMEN

ABSTRACT

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Construction projects are being tendered and implemented under different contract systems and payment methods. Design-Build (Turnkey) has been a popular contract system in recent years. It provides various advantages through entailing the contractor carrying out and being responsible for not only construction but also the design of the work. However, Design-Build turns to be a risky system for both Owners and Contractors unless the risks are identified, analyzed and managed throughout the tender preparation and project execution stages.

In this context, this study aims to present a literature survey on the issues of risk, risk analysis, risk management and Design-Build contract system in order to open a discussion and establish a managerial framework onto the potential risks inherent in Design-Build construction projects. Within the scope of the thesis, two case studies, one of which is hypothetical and the other is real, have been carried out for the purpose of illustrating how risk analysis and risk management techniques can be applied in fixed-price Design-Build construction projects and for showing the necessity of these applications for the success of such projects.

Key words: risk management, risk analysis, design-build, turnkey, contract system, construction projects.

ÖZ

TASARIM-YAPIM (ANAHTAR-TESLİM) SÖZLEŞME SİSTEMİ İLE İHALE EDİLEN İNŞAAT PROJELERİNİN RİSK ANALİZİ VE YÖNETİMİ

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İnşaat projeleri, farklı sözleşme sistemleri ve ödeme metotları ile ihale edilmekte ve yürütülmektedir. Tasarım-Yapım (Anahtar-Teslim), son yılların popüler sözleşme sistemi olmuştur. Bu sistem, müteahhidin sadece inşaat ile değil işin tasarımından da sorumlu olmasını gerektirdiğinden çeşitli avantajlar sağlamaktadır. Ancak; ihale hazırlık ve proje tatbik süreçleri boyunca riskler teşhis ve analiz edilip yönetilmedikçe, Tasarım-Yapım hem İşverenler hem de Müteahhitler açısından riskli bir sisteme dönüşmektedir.

Bu bağlamda, bu çalışma risk, risk analizi, risk yönetimi ve Tasarım-Yapım sözleşme sistemi konuları üzerinde bir kaynak araştırması sunmak ve böylece Tasarım-Yapım inşaat projelerinde mevcut olan potansiyel riskler etrafında bir tartışma açmak ve yönetimsel bir çerçeve kurmak amacını taşımaktadır. Tez kapsamında risk analizi ve risk yönetimi tekniklerinin sabit-fiyat Tasarım-Yapım inşaat projelerinde nasıl uygulanabileceğini göstermek ve bu uygulamaların bu tür

projelerin başarısındaki gerekliliğini ortaya koymak amacıyla biri kurgusal, diğeri gerçek olmak üzere iki örnek proje üzerinde çalışma yapılmıştır.

Anahtar kelimeler: risk yönetimi, risk analizi, tasarım-yapım, anahtar-teslim, sözleşme sistemi, inşaat projeleri.

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CHAPTER 1

INTRODUCTION

1.1 Background

Risk, which is a popular magical word, is frequently being used for qualifying many situations in daily life. It is improbable not to hear the classical sentences like 'Don't invest to this risky job', 'Driving fast at this terrible weather is risky' or 'It is uncertain that it will snow or not'. Increasing the number of similar sentences is easy. Then, what kind of definition can be put forward about this daily but also scientific concept and what is its difference from the term: 'uncertainty'?

Risk and uncertainty are sometimes used interchangeably. On the other hand, some authors like Pilcher [1] and Flanagan & Norman [2] emphasized the difference between these two terms as; 'risk' best qualifies the situations in which there are past records and experience, and decisions are made under the prediction of what is the chance or probability of the outcome, whereas 'uncertainty' best qualifies the circumstances of which it is impossible to attach any numerical or probabilistic quantities to the possible outcomes because of the lack of experience and past records. Nevertheless, such a separation has no meaning in construction investments. Flanagan & Norman [2] claim that even the most uncertain events in the construction sector can be redefined with some statistical values by means of the relevant past projects, experience, intuition and engineering judgment, and finally, these events are transferred to a risky environment by this way, no matter the predicted degree of quantification level is. For this reason, 'risk' will be the keyword throughout this study for discussing the construction events and contract conditions.

Although there are several specific definitions of risk, which differ with respect to the concerned field, they possess more or less the same content. Some examples are given below:

- "Risk is the possibility of loss, damage or any other undesirable event" [3].
- "Risk is the probability that an adverse event occurs during a stated period of time" [4].
- "Risk is the probability of occurrence of an undesirable outcome" [5] (p.6).
- "Risk is a condition in which there is a possibility of an adverse deviation from a desired outcome that is expected or hoped for" [6] (p.8).
- "A project risk is an uncertainty that may affect the execution or outcome of the project. The effect may be negative - a threat risk - or positive - an opportunity risk" [7].

All the definitions standing above share two common elements: indeterminacy and loss. In other words, in order to discuss about the existence of risk; first, there must always be at least two possible outcomes and second, at least one of the possible outcomes must be undesirable. For instance, if it is known that a loss will occur definitely, there can't be any risk [6].

The construction management literature contains similar approaches to the risk concept. For example, risk is generally defined, in a broad manner, as "an exposure to economic loss or gain arising from involvement in the construction process" [8-11]. Other extensive descriptions of risk, in the literature, are "any kind of event whose variation results in the uncertainty in the final cost, duration and quality of the project" [12, 13] and "the probability of occurrence of some uncertain, unpredictable and even undesirable event(s) that would chance the prospects for the profitability on a given investment'' [14].

The 'risk' subject has started to be discussed and investigated since 1940's especially in the insurance sector [15]. By the beginning of 1980's, this management concept has also entered into the construction sector. A great volume of scientific research has been carried out on construction risk management and analysis since 1990's. Furthermore, ''the period 1991-1997 has been a sharp increase in survey-based opinion research aimed at investigating the risk perceptions and risk management practices of construction clients, professional consultants and contractors'' [16]. This need has evolved due to the inherent risky structure and conditions of construction projects, not less but more than other business sectors. Inevitably, the need of performing risk analysis and risk management has risen up day by day due to the increasing complexity, size, competition, client-consumer requirements, politic-economic problems, heavy physical conditions and etc. So, in the course of time, the management of risk has become a key element for the completion of projects within time schedule and planned budget, especially in inflationary environments such as Turkey. It is now a common opinion that controllable and uncontrollable risks can only be responded by utilizing risk management process over the entire project, i.e. prior to the tender and subsequently, by controlling and updating the system periodically during the application of the pre-determined plan. In a broad sense, construction works have four important aspects that have to be concentrated on: time, cost, quality and safety. These four factors are considered as the main objectives of all construction works. Obviously, risk analysis methods and management systems try to ensure that 'all has been done' for the achievement of these main objectives.

Risk management can be defined as a systematic controlling procedure of risks that are predicted to be faced in an investment or project. Like every systematic procedure, it is a stepwise phenomenon. These steps can be summarised basically as risk identification, risk classification, risk analysis, and risk response [2]. Risk identification and classification comprise the qualitative investigation of the risks, whereas risk analysis part is dominantly quantitative and therefore, it includes mathematical and statistical operations. Risk response is the last risk management step at which the results of the preceding steps are discussed and suitable risk mitigation actions are taken in advance of facing with risks.

Construction projects are being tendered and executed under different contract systems and payment methods in nowadays. The construction contract systems can be categorised in basic terms as Design-Bid-Build (DBB), Design-Build (DB) and Construction Management (CM) [17, 18]. Design-Build has been a very popular system of the recent years for the reason it offers single point responsibility for both design and construction parts of the projects. In other words, "Design-Build contract system entails the contractor carrying out and being responsible for not only construction but also the design of the work" [19]. However, the owner employs different contractors for the execution of design and construction in the traditional Design-Bid-Build and Construction Management contract systems. The rising popularity of Design-Build system is due to its advantages with regards to project duration, project cost and innovative solutions of project problems. Unfortunately, besides its superiorities, Design-Build turns to be a risky contract system for both the owner and contractor unless the risks are identified in advance and managed throughout the project. Common construction project risks increase their intensity under Design-Build system in developing countries like Turkey and for this reason, risk analysis and risk management become vital tools for catching the success in Design-Build construction projects. Furthermore, Design-Build is a recently developing contract system in our country and therefore, Turkish owners and contractors who are not sufficiently aware of risk management and its necessity in Design-Build projects may fall into trouble as the utilisation of this system expands.

1.2 Aim and Objectives

The aim of this study is to open a discussion and establish a managerial framework onto the potential risks that exist within the construction projects tendered under Design-Build contract system.

The main objectives of the thesis is to clarify and compare the characteristics of Design-Build contract system with respect to alternative construction contract systems, and to provide basic information about project risks and applicable risk analysis/management techniques in construction projects.

The purpose of the case studies carried out towards the end of the thesis is to present the applicability and necessity of risk analysis and risk management techniques in Fixed-Price Design-Build construction projects.

1.3 Methodology

A literature survey is made in order to present the characteristics of Design-Build contract system and to give its historical background. The survey also consists of information about risk analysis techniques, risk management system and its evolution.

Two case studies are carried out after providing the theoretical background. One is hypothetically formed on a private-sector fixed-price Design-Build construction project whereas the other is about a completed public sector construction project.

Both of the projects belong to the Turkish practices i.e., they are carried out and discussed according to the conditions of Turkey. In addition, new approaches and proposes are tried and developed through the risk analysis part of the hypothetical case study.

1.4 Scope

This thesis involves the results of a literature survey made on the risk analysis, risk management and Design-Build contract system. Since the research is performed by means of international resources, the results are valid and useful for all relevant construction projects. However, the case studies cover only Turkish Design-Build applications. Moreover, they dominantly cover cost, schedule and contract risks that are encountered in fixed-price Design-Build construction projects. The risks that are effective on quality, safety, operation and which are subject matter of insurance will be out of the scope. The reason for this is that the project managers are mostly concerned with the effect of risks on the target completion date and the proposed cost of the project although project risk management must also include the environmental, political, technical and safety risks that may arise during the life of the project [7]. For this reason, the risk analysis part of the case studies include only time schedule risk analysis and cost risk analysis of the projects, and accordingly risk management is applied around the schedule and cost risks.

1.5 Outline

In chapter 2, a literature survey is made on the possible construction risks, risk management stages and risk analysis techniques. At the end of the chapter, the future of risk management in Turkish construction sector is discussed and popular risk analysis computer programs used worldwide are evaluated.

Chapter 3 includes basic information about the construction contract systems, construction contract payment methods and a wide explanatory research about Design-Build contract system.

Chapter 4 includes the first case study of the thesis. It is a hypothetical study built on a real scenario related to a state bank in Turkey. 'How Design-Build contract system is applied' and 'how risk analysis and risk management can be performed in a Design-Build construction project' are investigated within this study.

Chapter 5 consists of the second case study. It is a discussion over a completed public sector Design-Build construction project of Turkey. The results of the project are evaluated in terms of time and cost risks.

The results provided throughout the thesis are emphasized at the last chapter (chapter 6), which is the conclusions and recommendations part. As its name implies, recommendations concerning the future works are also given within this chapter.

CHAPTER 2

RISK MANAGEMENT SYSTEM

2.1 Introduction

This chapter consists of broad information about construction risks, contract-risk relationship, project risk management system, risk analysis techniques, risk analysis software and construction risk analysis models. On the other hand, the chapter's focus point is not only investigating risk management in construction projects but also approaching the subject as a general management methodology that is further applicable to the projects of other sectors. Furthermore, the future of this new managerial discipline and Turkish construction companies' perceptions of risk management are being discussed towards the end of the chapter.

2.2 Risks in Construction Projects

Each project in the construction sector has its own technical characteristics that vary according to the construction type. For instance, highway construction will differ from building construction due to the consumed construction materials, applied activities, physical-geographical conditions, specifications and so on. This creates a different risk atmosphere for each construction project. Furthermore, potential risk sources affect the course of the project at each step from the preliminary design stage till the commissioning stage. The basic stages of construction procurements are given below in advance of proceeding to the discussion of various kinds of construction risks [17, 20]:

- Stage 1 – Program planning, appraisal, preliminary design
- Stage 2 – Tender, awarding, sanction
- Stage 3 – Project planning, engineering
    * Design
    * Activity planning
    * Construction
- Stage 4 - Commissioning, delivery
- Stage 5 - Operation, maintenance

Obviously, each of the project stages established above consists of both different and common types of risks and these risks affect different parties involved in the project in different ways. For example, stage 1 (program planning, appraisal, preliminary design) is mainly related to the owner and therefore, he/she is the owner who should mainly deal with this stage's possible risks in order to avoid the negative effects that would also affect the next stages. Stage 2 (tender, awarding, sanction) comprises the risks that mainly influence the decisions of contractors. The contractor estimates and offers the cost, deadline and sometimes the quality level at this stage. The owner is also in a risky position because he/she should select the most appropriate contractor at this stage for the sake of project success. The classical approach, 'selecting the contractor who suggests the lowest tender price as the winning contractor' is occasionally wrong and dangerous. Figure 2.1 illustrates the project stage – risk relationship in a more simplified way.

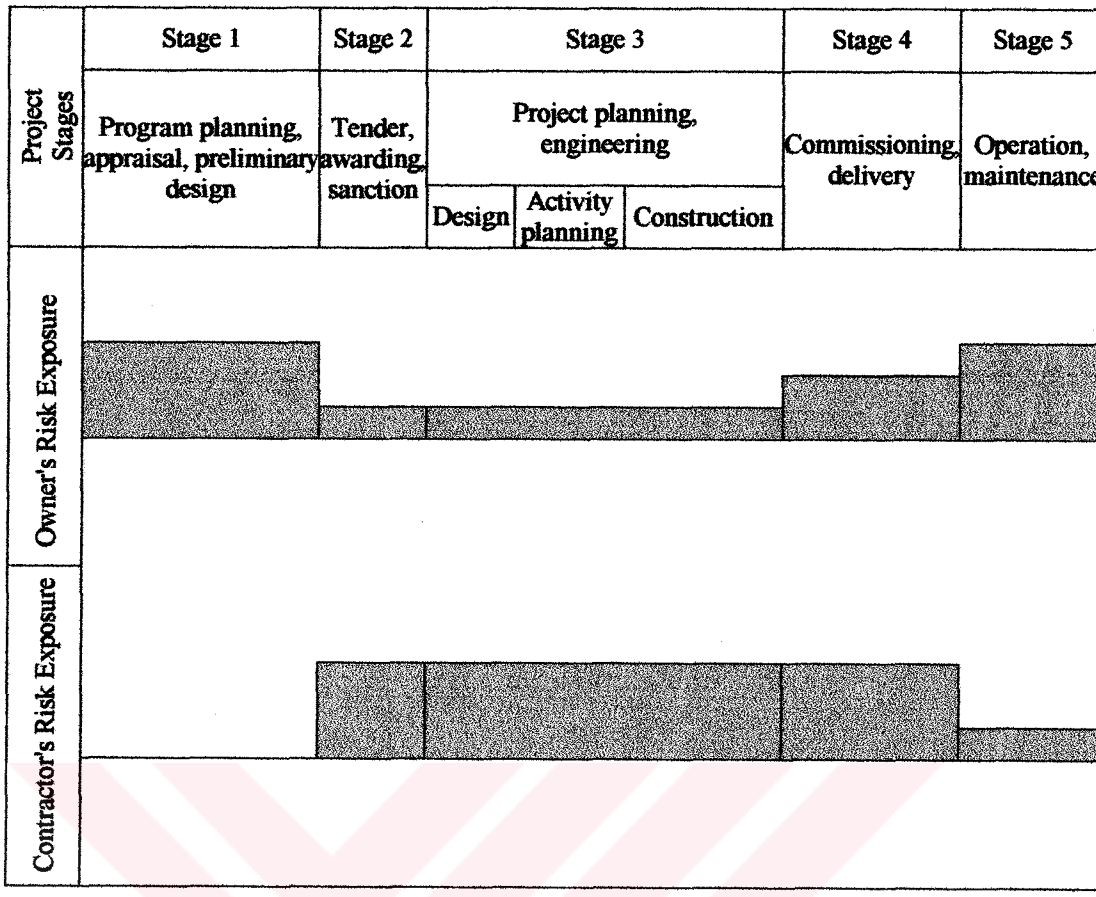

Figure 2.1 Project stage – party – risk exposure relationship

Past records can be helpful up to a certain extent, due to the uniqueness of each project, in identifying the inherent risks of the coming projects. Then, managing the risks in construction projects turns to be also a matter of common sense, analysis, judgment, intuition, experience, gut feel and willingness [2].

Different types of risk lists are available in the literature because of the different approaches to the risk classification subject. However, the content of these lists are almost the same and all of them may be complementary in setting up a risk management system. Furthermore, they indicate the same point when the consequences of the construction risks are concerned. Table 2.1 lists the major risks encountered in different stages of construction projects, without separating the risks into source types. Additional specific risks may be entered to the list according to the country at which the commitment is procured and undertaken.

Table 2.1 The list of main construction risks [21, 22]

RISK NO.	RISK NAME
1	Delayed site handover
2	Political instability
3	Bureaucracy
4	Changes in laws and regulations
5	Inadequate specifications
6	Inability to evaluate bids on time and by means of an adequate procedure
7	Delays in resolving disputes
8	Change in taxation system
9	Delayed progress payments
10	Difficulties in obtaining credits
11	Inflation
12	Exchange rate fluctuations
13	Interest rate fluctuations
14	Difficulty stemming from extraordinary project financing models
15	Labor disputes, strikes, lock-out
16	Accidents
17	Low productivity (equipment, labor)
18	Difficulties/delays in availability of materials, equipment, labor
19	Third-party delays
20	Inadequate quality of work and need for correction
21	Changes in quantity/scope of work
22	Client delays (unable to get approvals, lack of payment, etc.)
23	Unforeseen ground conditions
24	Exceptionally inclement weather
25	Natural hazards (earthquake, flood, fire, storm, landslide)
26	Social events, terror
27	Restrictions due to precaution against environmental pollution
28	Delays in design
29	Defective or incomplete design
30	Lack of experience about the applied construction techniques
31	Financial failure of any party in the contract
32	Insufficient demand in construction sector (not obtaining long term works)

The major effects of the risks listed in Table 2.1 over the project are as follows [2]:

- Failure to keep within the cost estimate
- Failure to achieve the required completion date
- Failure to achieve the required quality
- Failure of the project to meet the required operation needs
- Failure of the project safety requirements
- Damage as a result of fire, flood, earthquake, etc.

2.3 Risk Management System - Definition and Framework

All the effort consumed in any project or investment is for the purpose of catching the success level that was previously decided. This is not only a soft aim in many cases. The need of success is vital for the companies that desire to make profit, and which dream of growing up and protecting their reputation. Moreover, this is valid for the companies of all sizes that operate in various sectors. The successes of the national or international companies of a country are also a factor of the economic development level of this country and a factor affecting its political power.

The planned company goals can only be achieved by taking realistic and logical investment decisions. Afterwards, the succeeding issues would be the right resource allocation, comprehensive feasibility study, logical project plan and proper management. Strategic management and risk management, which can also be considered as an important tool of strategic planning, have recently been the other company success agents in both micro and macro-level, because risk management and analysis submit a useful framework for understanding, formulating and solving the complex planning problems [23]. Researchers have already explored the fact that there is a strong link between the amount of risk management undertaken in a project, and the level of success of the project. Also they claim that the earlier risk management is used in a project, the more successful it is [24].

Risk management never avoids the inherent risks of a project or business. In contrast, the risks always exist but a systematic identification and analysis approach along a managerial frame definitely help manage and decline the harmful effects of them. Furthermore, the updating character of the risk management system throughout all the project steps introduces an additional power for optimizing the risk response strategies.

Risk management can be defined as a system of identifying and quantifying the risks that can be faced in a business or project so that a conscious decision can be taken on how to manage the risks. It is neither an insurance system nor a magical risk elimination method. It only aims to identify the potential risks as early as possible and manage them for preventing the harmful effects of the risks to the project aims. The system utilizes the historical data, statistical knowledge, computer modeling-running power; human intuition, judgment, experience, gut feel, common sense and willingness up to a full extent. However, a risk management system should be realistic, practical and cost effective [2]. Besides, risk management can be considered as an integral part of project management.

There are many other approaches to the definition and scope of risk management system. For instance, some researchers have identified it as a multiphase system that covers identification, evaluation, control and management of risks [25-27]. Moreover, it has been proposed as a sequence of steps consisting of risk identification, risk measurement, risk evaluation and re-evaluation and linked with strategic management and planning [28].

Charette [29] preferred to separate risk management and risk analysis, and consider them as the basis of risk engineering. However, the European Community has developed a more comprehensive risk management methodology under the name of RISKMAN. The method consists of the following steps [30]:

- Risk identification
- Risk assessment
- Risk evaluation
- Risk mitigation
- Contingency estimate
- Decision making
- Control and monitoring

Tummala [31] has developed a specific system called Risk Management Process (RMP), which is a slightly different risk managing technique. RMP has been defined as "a systematic framework to enumerate and assess the consequences and the likelihood of their occurrences of all potential risk factors associated with a given project" [31]. The framework of RMP is illustrated in Figure 2.2.

Fortunately, all of the approaches given so far have common basic steps. This reality makes it possible to produce a more simplified risk management framework. Flanagan [2] has already developed such an easy methodology as shown in Figure 2.3. This framework will be accepted as the base risk management model and will be discussed furthermore along the coming sections of the chapter because of its sufficiency for managing construction risks. Another superiority of this model is its easiness for all the participants of a project to understand the system. Moreover, as the model is simplified, it also becomes easy for the risk manager to describe the necessity of the risk response precautions to the senior management.

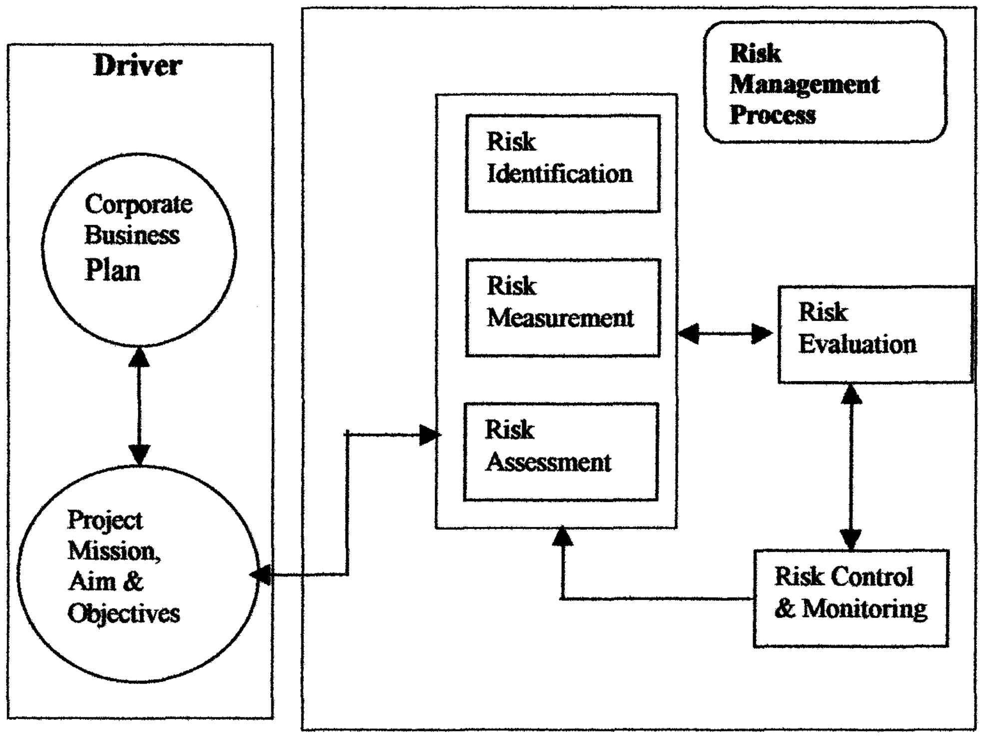

Figure 2.2 The risk management process [31]

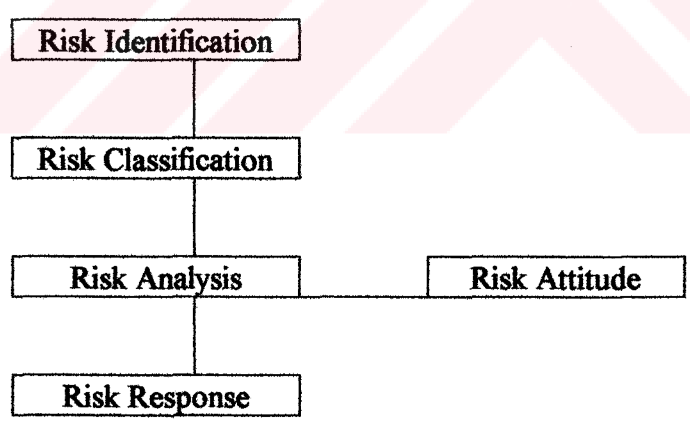

Figure 2.3 The risk management framework [2] (p.46)

2.3.1 Risk identification

The first step or first task to be carried out for building a risk management system is to identify all risks to which the business or project may be exposed. The strict obligation on this task is due to the impossibility of performing analysis and developing risk-tackling strategies without having detailed knowledge about the project risk sources and effects.

Risk identification is a never-ending activity because new risks are arising continuously. This leads to the fact that no one can be sure of having performed the identification process perfectly [6]. In fact, risk identification is the job of professionals, just as the remaining steps of the risk management system. While larger companies have been instituting risk management departments within their organizations especially for the last decade, middle-small scaled firms occasionally employ risk management consultants in developed countries.

Risks should be identified in a systematic and structured way for the sake of comprehensiveness. The sequence to be followed may be in the source-event-effect order. The Figure 2.4 shows an example of a systematic and structured risk identification sequence. Moreover, the risk sources may be categorized as controllable, uncontrollable, dependent, independent, totally dependent or partially dependent. This procedure clarifies the character of the source [2]. For instance, weather risk is an uncontrollable risk. However, it can be broadly converted to a controllable form by applying radical modifications on the schedule plan through deep investigations related to the meteorological records. As another example; the selection of a particular construction plant in a project depends on the technical, economic and schedule needs, and assume that the selected plant mainly consists of heavy construction machines. Economy related risks exist in this case due to the dependence of the plant on the petrol prices. An increase in petrol prices because of complex global reasons will probably increase the plant operation costs. Here, it can be claimed that such kind of a risk is uncontrollable. This is true. Nobody included in the project can prevent a rise-up in the price of oil generated due to the international political problems. However, in some sense, it is also a kind of partially dependent risk and controllable for the reason alternative plants can be hired in order to struggle against the possibility of petrol price increases.

Probable Sources	**Event**	**Probable Effects**
• Inflation	Increase in the Cost	-Project cost increase
• Devaluation	of an imported special	- Late delivery of the
• Cost escalation	Building Material	material and project
• Quantity increase		being delayed due
• Transportation cost	→	to the insolvency of
increase		the contractor
• Customs tax increase		- Loss of morale

Figure 2.4 An example of systematic risk identification sequence

The reality, logic, experience and detailed investigation are the other factors lying under any successful risk identification process. "Inevitably, bad definition of a risk will breed further risk" [2] (p.47). Once a risk is identified realistically and properly, it can be claimed that it is not a risk henceforth, but instead a management problem.

The common risks encountered in construction projects have been listed previously in Table 2.1. It is obvious that the risks affecting a particular project might not absolutely affect the other projects at the same level. Therefore, the appropriate risk identification methods should be applied especially at the preliminary appraisal stage in order to clarify all the project risks. Sometimes, "a combination of identification methods may be required" [32] (p.105). "Certain methods are more appropriate for some industries and in some circumstances than others" [32] (p.105). Some of the risk identification techniques and tools are as follows [6, 21]:

- Risk analysis questionnaires: Risk analysis questionnaires are tools designed to lead the risk manager to the discovery of risks through a series of detailed questions.
- Exposure checklists: Exposure checklists are lists of common risks. This identification tool can be used effectively in conjunction with other risk identification tools as a final check to reduce the chance of overlooking a serious risk exposure.
- Insurance policy checklists: Insurance checklists can be provided from insurance companies. Such lists include a catalogue of insurance types. Risk managers consult such a list in order to pick out the policies applicable to the firm or the business.
- Expert systems: An expert system used in risk identification incorporates the features of risk analysis questionnaires, exposure checklists, and insurance policy checklists in a single tool. Expert systems lead the user through a series of detailed questions designed to assist in identifying not only common risks, but also those that may be unique to the specific business or project.
- Risk mapping: Risk maps are two-dimensional scaled graphs prepared for identifying the probability of occurrence of a risk and its potential severity. The potential severity and probability of a risk help the manager with deciding whether it is an important risk or not.
- Brainstorming: Brainstorming is simply discussing a problem within a group in order to produce a solution. It can be useful both in risk identification and qualitative risk analysis.
- Interviews: Interviews made with key personnel within the organization generally provide important information that can aid in risk identification.
- Risk category summary sheet: Risk category summary sheet is prepared at the end of a risk identification process with the participation of all the personnel in the project team.

Nevertheless, the most widely used techniques are risk checklists compiled from previous data and experience, interviewing with senior project personnel, and brainstorming with the project team [33, 34].

In fact, identifying the risks that might be effective on the project aims is the most important activity of any risk management process because the explored risk sources at this step would be the data of succeeding steps. In case of improper execution, the analysis results would not be realistic and the determined strategies would be insufficient. Furthermore, the risk identifying procedures have to be applied as early as possible before the project period or during the preliminary design stage, and they should be repeated and updated throughout the project. Otherwise, the disastrous effects of the risks cannot be avoided.

2.3.2 Risk classification

While risk identification is the process of searching the possible risks that can be encountered throughout the project life, risk classification, which is the next step, is all about grouping the pre-identified risks according to certain criteria. The aim of the procedure is to organize the scattered risks in order to get a more comprehensive risk and project view.

The risks can be classified in three ways [2]:

- Determining the type
- Identifying the consequence
- Forecasting the impact

The first way, which is the classification by determining the type, is separating the risks as pure and speculative. The risks that create no gain are considered as pure risk, whereas the risks with which the loss or gain is possible are speculative. For instance, undesired weather risk is a kind of pure risk; it has no advantage. In contrast, restrictive conditions of contract can be represented as speculative risk because the strict contract conditions might focus all the parties onto a single point: success. This situation might also be advantageous as well as disadvantageous.

The second way, classifying through identifying the consequence provides efficient results to be used during the risk analysis stage, because the risks are classified according to their effects on the main project purposes, which are completing the project within budget/schedule and in compliance with the quality/safety specifications. This helps the risk manager use the identified risks realistically during the analysis and afterwards find the appropriate risk response methods. As an example, inclement weather risk is mainly effective on the project schedule (duration) although it can be claimed that it would also be an influencing factor of the project cost (budget) and safety unless precautions were not taken. Therefore, the weather risk should be taken into account especially during schedule risk analysis; adding that it is also an effective agent in cost risk modeling and safety management.

The third and last way of risk classification is simply categorizing the risks according to their impacts either on the project, company, industry/sector or environment [2]. The intended meaning with 'environment' is two sided: physical environment and social environment. Weather and natural disasters constitute the physical environment and for this reason, the relevant risks are uncontrollable. On the other hand, social environment consists of political, economic and sociologic issues and mainly the relevant risks are partially controllable.

While environmental risks and sector risks can be evaluated as macro-level risks, project and company risks become micro-level, accordingly. Furthermore, environmental risks may affect all the society or industrial risks may affect all the market of the same character but the company or project risks are only associated with the related project or the company. For instance, the economic crisis that has been experienced in our country by the end of 2000 is an environmental risk. Another example is the increasing competition risk in the national construction sector of Turkey. However, this is only a kind of sector or industry risk. Owner's delay of payment in a particular project for a long time can be considered as a company risk in case the company simultaneously undertakes more than one project, because such a problem concerning the budget of a specific project may affect the other projects' budgets as well. In contrast, injury of a workman is only a project risk, because it is only effective within that particular project.

Table 2.2 is an example to the risk classification procedure described up to here.

Table 2.2 A tabular example of risk classifying application

RISK DESCRIPTION	TYPE	IMPACT	CONSEQUENCE
• Inflation	Speculative	Environmental	Cost
• Payment Delay	Pure	Company Project	Cost Duration
• Unforeseen Ground Conditions	Pure	Project	Cost Duration
• Political Instability	Speculative	Environmental	Cost Duration
• Injury of Workmen	Pure	Project	Safety
• Strike of the workers of a particular sector	Pure	Sector	Cost Duration

2.3.3 Risk analysis

The next stage after risk identification and classification is risk analysis in a risk management system. Risk analysis covers both quantitative risk measurement and qualitative risk assessment techniques and for this, statistical methods, simulating/modeling capabilities of computers, engineering judgment and risk attitude are all taken into account and utilized. The importance of risk analysis is that it shows what happens if the project does not proceed according to the plan due to potential risks and warns the decision-maker or manager about the necessary responses to cope with risks. Furthermore, it captures all the feasible options and analyses the various outcomes of any decision [2].

The activities of a risk analysis process can be summarized as follows [32]:

- Identification of risks to be analyzed
- Quantifying the consequences if the risks occur
- Determination of the probability of occurrence
- Calculating the risk and prioritizing in order of importance.

Risk analysis techniques are grouped in two parts: quantitative and qualitative. They benefit from the data produced by risk identification and classification but qualitative approach consumes the gathered information through direct judgment, ranking options, comparing options and descriptive analysis. In contrast, some of the quantitative risk analysis techniques, like Monte Carlo simulation, are used in performing statistical models and simulations in order to reach numerical results that show the effects of risks. Whilst the most tools and techniques used in analyzing the risks provide quantitative solutions, they all constitute some subjectivity.

There are a number of quantitative risk analysis techniques. They can be classified as classical techniques (e.g., sensitivity analysis and Monte Carlo simulation) and conceptual techniques (e.g., fuzzy set analysis) [35].

Some of the common risk analysis techniques are enumerated below [2, 21]:

- Sensitivity analysis
- Monte Carlo simulation
- Decision-tree analysis (stochastic or deterministic)
- Fuzzy-set theory
- Utility theory
- Multi-attribute value theory
- Bayesian theory
- Portfolio analysis
- Breakeven analysis
- Scenario analysis
- Delphi method

The quantitative risk analysis techniques can be further classified as deterministic and stochastic techniques. The stochastic methods such as Monte Carlo simulation, stochastic decision tree analysis, Delphi method and portfolio analysis produce probabilistic solutions instead of assuming %100 certainties for decision variables like deterministic analysis techniques. Deterministic techniques such as sensitivity analysis, scenario analysis, breakeven analysis and deterministic decision tree analysis produce fixed single-value estimates. In contrast, the variables in a stochastic risk analysis model can be represented by probabilistic terms or distributions so that the uncertainty surrounding the project is assessed. For these reasons, stochastic risk models and analysis techniques are becoming more popular among project managers and decision-makers.

The following subsections consist of wider information about sensitivity analysis, breakeven analysis, scenario analysis, Monte Carlo simulation and decision tree analysis (deterministic and stochastic). The reason of describing only these techniques is for not running over the scope and also due to the fact that those are the most common techniques used in practice.

2.3.3.1 Sensitivity analysis

Sensitivity analysis is a kind of 'what-if' analysis. It aims to answer the questions like 'How does the total project cost change if inflation rate increases 5%, 10%, 15%... above the estimated base inflation rate with the other cost affecting factors are kept constant?' In other words, sensitivity analysis is a kind of deterministic risk analysis technique that is used to observe the impact of a change in the value of an independent variable on the dependent variable [2]. There are two major uses of sensitivity analysis:

- It identifies the risky sides of the project in order for concentrating on these sides.
- It identifies risky variables that change the ranking order of the alternatives, so that effort is concentrated on these areas.

Sensitivity analysis provides useful solutions especially for economic decision-making, cash flow risk modeling and cost risk modeling. Nevertheless, it is also used in schedule risk models.

The results of sensitivity analysis can be presented in several ways. Sensitivity tables and graphs are the most widely used tools. A particularly effective graphical presentation of sensitivity analysis is the spider diagram. Moreover, spider diagrams are used for comparing and ranking the options concerning different economic alternatives.

The steps of constructing a spider diagram related to cost risk analysis of a project as an example are listed below [2]:

1. Calculate the project cost using best estimates of all parameters.
2. Identify the parameters subject to risk and uncertainty.
3. Select one of the risky parameters and recalculate the project cost assuming that this parameter is varied by x%, where x lies in some predefined range such as $-5 < x < 5$.
4. Plot the recalculated project costs on the spider diagram, interpolating between each value.
5. Repeat steps 3 and 4 for the remaining parameters that have been identified as risky.

An illustration of spider diagram is given in Figure 2.5. The point at which the parameter lines intersect is the best estimate point. It is calculated by using the most likely values of the parameters. As a percentage change is observed in one of the parameters, the best estimate point moves on its own axis. The shape and slope of the parameter lines give idea about the effect of the parameter on the total cost i.e., the flatter the parameter line, the more sensitive project cost will be to variation in that parameter. The counter lines drawn between the parameter lines in the figure are called probability counters. These are built subjectively by identifying the range, that a particular parameter is expected to lie on, at each level of probability. For example, it may be estimated that there is 60% probability that the parameter 1 will lie in the range between +2,5% and –3,5% of the best estimate, and parameter 3 will lie in the range between +2 % and –4% of the best estimate. Whilst the subjective determination of the probability counters seems to create an unrealistic picture, they can be developed if statistical data concerning the variables exist.

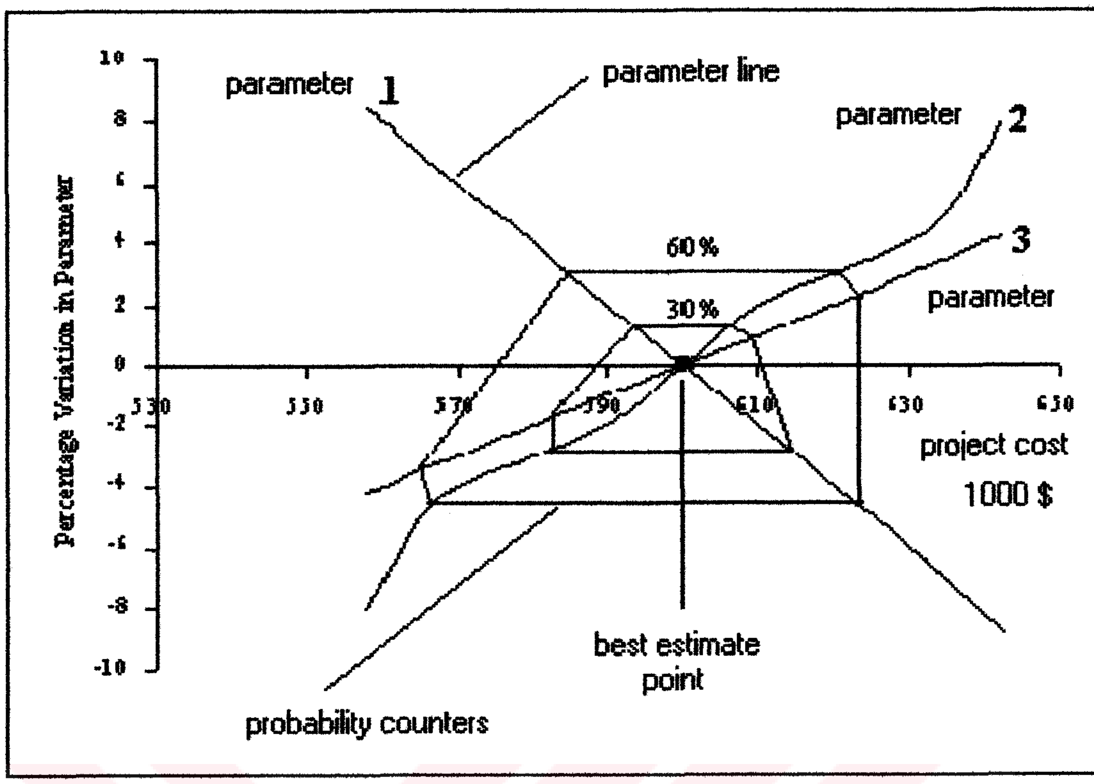

Figure 2.5 Spider diagram (an illustration)

Sensitivity analysis has also some drawbacks. These are given below [2, 33]:

- The occurrence probabilities of the risky variables are not taken into account.
- Interdependence between the variables is ignored.
- The effect of only one variable's change can be observed at a time, although there exist infinite number of combinations of the variables for which the project is affected. The whole picture is not reflected.
- It does not provide a definite method of making a choice between the competing options.

2.3.3.2 Breakeven and scenario analysis

Breakeven analysis and scenario analysis are, in some sense, the applications of sensitivity analysis. Breakeven analysis is used for verifying the key variables of a project, which show the project is attractive or not. It can be considered as a dynamic decision-making or cash flow risk-modeling tool. First, a break-even rate (critical rate of return) is found by equating all probable cash flows with the initial capital cost. Then, changing the variable values, one at a time, their impacts on the break-even rate are observed [2, 36].

Scenario analysis is applied when testing alternative options. The options are regulated and then evaluated as different scenarios, but the scenarios should be based on the most likely, the optimistic and the pessimistic forecasts. Besides, only key variables are identified with their values. Scenario analysis can also be used for optimization purposes [2, 36].

2.3.3.3 Monte Carlo simulation

Monte Carlo simulation (MCS) is a very widely used risk analysis simulation technique. Simulation has already been performed in many branches of science in order to observe and estimate the real behavior of a system or process prior to its execution. Yet, Monte Carlo simulation is a kind of stochastic and statistical experiment applied for practicing randomly generating events that cannot be formulated by even empirical means. For this reason, this technique is particularly useful when processes or events are too complex to be solved analytically [2, 37].

As an example to give the logic of Monte Carlo simulation, suppose that we want to know the possibility of getting 3 when we roll an unbiased dice. The answer of this very simple probability question is obviously 1/6. The same result could have been found by rolling the dice thousands of times and recording the frequency of getting 3, but there is no need to do this due to the existing mathematical solution. However, what will happen if we want to find the probability of getting a total of 10 or more in case of throwing 5 dice, and furthermore each of them is identically biased so that the probability of getting a particular number between 1 and 6 is 0.2, 0.1, 0.4, 0.05, 0.06, 0.19, respectively. It is apparently very difficult to solve this problem analytically or through testing. In contrast, it is very easy with Monte Carlo simulation. First, the biased features of the dice are represented by appropriate probability distributions; second, this statistical data is modeled on a spreadsheet and next, Monte Carlo simulation is carried out by performing the experiment thousands of times on a computer environment [37].

All projects and investments consist of many randomly based events or activities like above examples. For instance, the total cost of a project cannot be calculated exactly by formulas in advance, because of the complex market conditions, human factors, physical environment and many other risks. However, it can be estimated statistically by Monte Carlo simulation because it is a random process. Monte Carlo simulation enables the risky project parameters to vary simultaneously according to the attached probability distributions explored from previous data. As the iteration number of simulation is increased, more regular and consistent results are provided related to the variable sides of the project. Furthermore, the risk model on which the Monte Carlo simulation is performed can be further developed by necessary formulas and correlation values before the simulation.

The steps of a standard risk analysis process using Monte Carlo Simulation are as follows:

- Determine the project risks and relevant activities

- Attach the appropriate probability distributions to the activities taking the risks into account
- Specify and establish the correlation coefficients between the parameters
- Develop the spreadsheet model in accordance with the accumulated data
- Arrange the simulation preferences
- Run Monte Carlo simulation
- Evaluate the statistical results
- Update the model and repeat the simulation

The most sensitive issues of Monte Carlo simulation are the determination of probability distributions and correlation coefficients. Three approaches to the definition of the distributions exist in the literature: subjective definition of the distributions by expert judgment, objective definition of the distributions from the historical data and objective/subjective definition from a small sample of data extracted from previous similar projects [38]. All of these approaches are valid in different circumstances because the amount and consistence of historical data is the key criterion that determines the way to be followed.

The followings are some of the common distribution types utilized in Monte Carlo simulation [2]:

- Uniform
- Triangular
- Poisson
- Binomial
- Lognormal
- Exponential
- Geometric
- Hyper geometric
- Weibull
- Beta

It is sometimes difficult to determine the appropriate distribution for a variable. In order to overcome such difficulties, the properties of the distributions and the factors surrounding the variables should be properly investigated. Moreover, statistical goodness of fit tests and regression methods, such as chi-square, Kolmogorov-Smirnov, Anderson-Darling tests and least squares method, can be applied on the previous data [5]. The following list consists of the basic principles to be followed in selecting probability distributions [2].

- The distribution should be easily identifiable from a limited set of data
- The distribution should be easily updated as additional historical data are introduced to the analysis
- The distribution should be flexible in shape i.e., it should be capable of taking a variety of shapes
- It is better for the analysis that the distribution has finite end points

Some of the distributions are more suitable in particular conditions. For instance, discrete functions are seldom used in construction cost risk analysis, whereas positively skewed triangle, beta and lognormal distributions are the most frequently used types for this purpose. Figure 2.6 illustrates the common distribution types used in construction risk models.

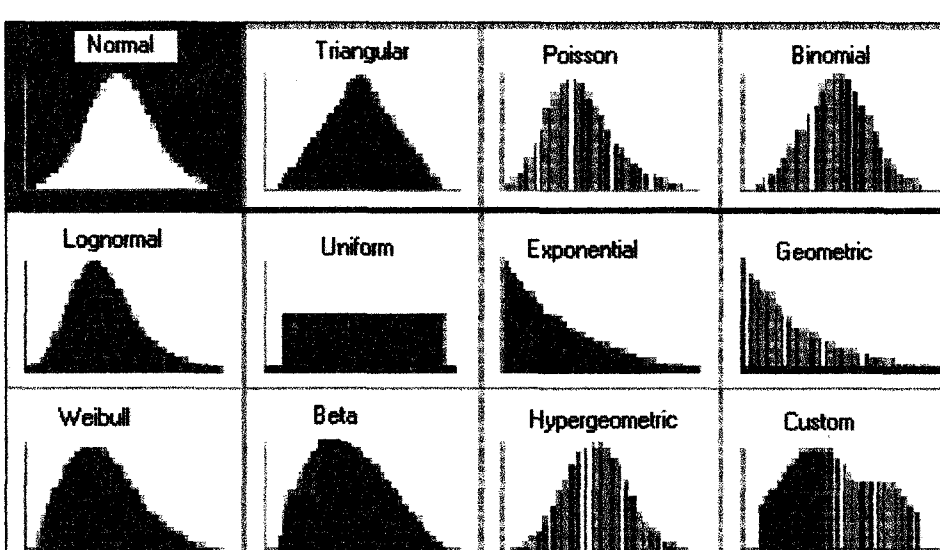

Figure 2.6 Common distribution types [3]

Monte Carlo simulation uses random numbers chosen from the predefined value ranges of variables. These random numbers are generated by random number generators of computer programs and consumed to generate outcomes from the probability distributions in correspondence with their statistical properties and shapes [5].

Although it seems very important to choose the right probability distribution type for the project variables in Monte Carlo simulation, the fact is not like this. The reason is that the errors in selection of distribution types are compensated by the effect of central limit theorem [5]. "Central limit theorem implies that when a range of distribution shapes are entered and simulated many times, there will, as the number of simulations increases, be a tendency for the output distribution to tend to the normal shape" [15]. Therefore, selection of the precise distribution type is not more important than establishing the correlation effect in the model. This fact is more evident in particular areas. For instance, Wall [38] claims that it is relatively more important to investigate and allow correlations between the costs of sub-components of construction cost estimates than to select the best-fit distribution to represent cost elements in Monte Carlo simulation. Correlation between the variables may be positive or negative and this is represented by correlation coefficients between 1 and –1. Relevant computer programs are capable of estimating correlation coefficients between the variables if correlation exists. Furthermore, they can warn the user if there is some inconsistency between the entered coefficients. However, estimating the correlation between the variables is not so easy. It depends on deep experience and the amount of previous data in hand.

The results of Monte Carlo simulation may be arranged in different forms according to the purpose. These are tabular summary lists (Table 2.3), frequency diagrams (Figure 2.7) or cumulative frequency diagrams (Figure 2.8). Summary lists show the probability ranges of the required resultant variable such as project duration or total cost, statistical properties of the results and summarize the critical parameters of the risk model. They generally do not contain graphical representation like frequency and cumulative frequency charts. Frequency charts show the range of the values and corresponding frequencies (probabilities) of the resultant variables in diagrams. The difference of cumulative frequency diagrams from tabular list is that they are in the form of cumulative frequency histograms produced from the frequency diagrams. All of the forms can be used in parallel for the sake of comprehensiveness at the risk evaluation and risk response stages.

Table 2.3 An example tabular list showing the results of a MCS

Percentile	Total Price (TL)
0%	106.695.727.788
10%	113.013.205.359
20%	114.322.978.034
30%	115.469.215.795
40%	116.517.456.612
50%	117.281.208.048
60%	118.272.780.980
70%	119.001.406.554
80%	120.439.946.558
90%	122.093.287.950
100%	126.947.273.416

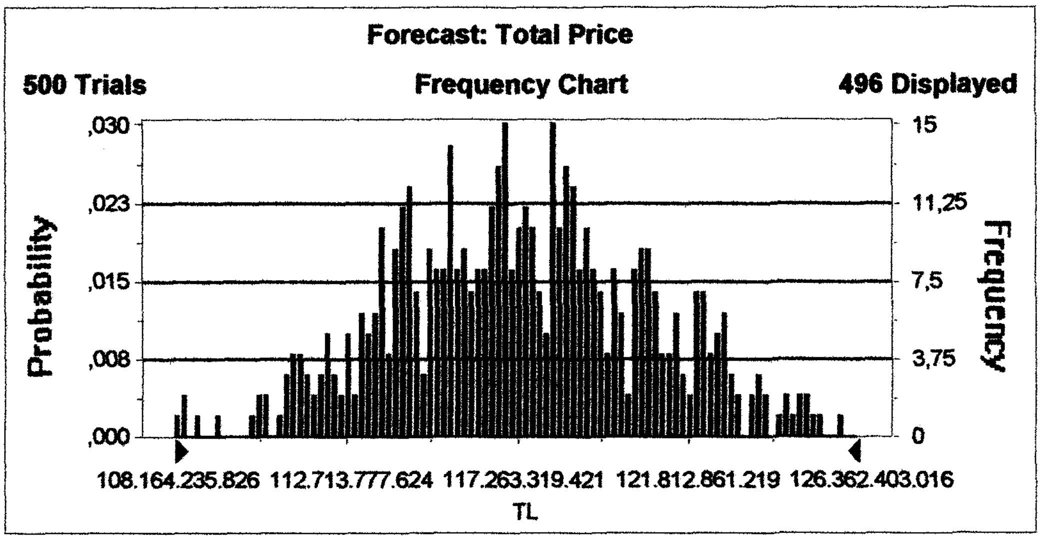

Figure 2.7 An example frequency diagram

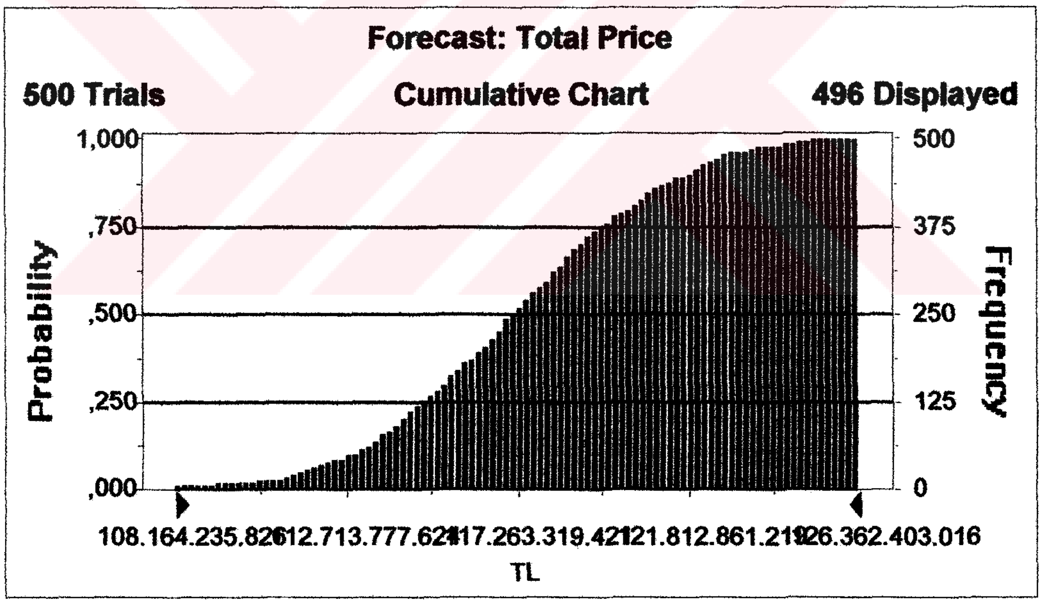

Figure 2.8 An example cumulative frequency diagram

2.3.3.4 Decision tree analysis

Decision tree analysis is another powerful technique that is used for decision-making related to various alternatives during an investment decision, project execution or project selection. Its name comes from the shape it takes, as the sequence of decision points and chance points are arranged one after another just like a tree. Figure 2.9 represents a simple decision tree illustration [1]. The rectangular box is the decision point and the others, which are circular, are the chance points in this figure.

The way to be followed at decision points depends on the decision-maker. Nevertheless, the same thing cannot be said for the chance points, i.e. chance points separate into different alternative branches of different probabilities. All of the alternative branches formed by decision and chance points finally build different strategies with different expected monetary values. The decision maker makes decisions according to the resultant expected monetary values of these alternative branches. The bigger the alternative's expected monetary value, the more appropriate it is to choose that alternative.

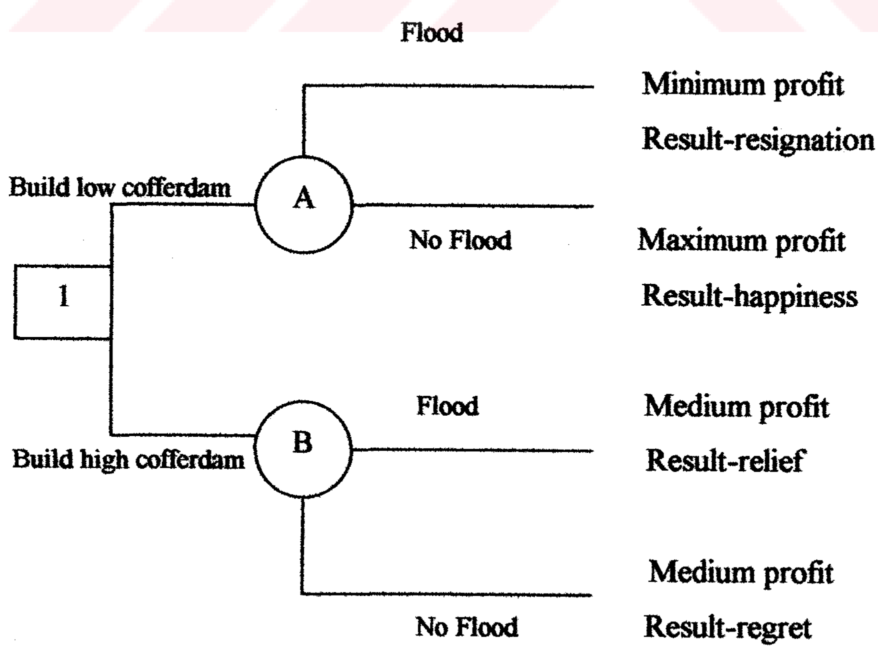

Figure 2.9 Decision-tree (a simple illustration) [1] (p.98)

Except for deterministic decision-tree analysis described above, there also exists a similar technique, which joins Monte Carlo simulation and decision-tree logic. It is stochastic decision-tree analysis. Stochastic decision-tree analysis is an advanced version of decision-tree analysis. The superiorities of this technique can be summarized as below [23]:

- The resultant information about different alternating branches is obtained in the form of probability distributions.
- The resultant probability distributions are analyzed by using risk management concepts.

The chance points of stochastic decision-trees are represented by probability distributions. Net present value criterion and related statistics of options generally become the key items in evaluating the results of stochastic decision-tree analysis. However, both variance and expected monetary value criterions can also be used in connection in stochastic approach. The bigger the alternative's expected monetary value and the smaller its variance, the more appropriate it is to choose as an alternative.

Decision trees have the advantage of forcing the decision-maker to structure the problem with which he is dealing in a consistent and objective manner. Furthermore, they clarify the risky points and show which decisions are dominated by the other choices. For this reason, they are extensively used in managerial decision-making [2].

2.3.4 Risk response

The last action of systematic risk management process is responding to risks. The results of the preceding stage are evaluated and accordingly, the strategies to cope with risks are determined during this stage. Contracts, insurance and surety are the common means of risk response by which the determined strategies are documented and carried out. Although, some of these means are expensive reactions they should not be considered as wasted costs. In contrast, they are the precautions to generate the desired returns [2].

The risk response strategies can be categorized in four groups [2, 21, 32, 34]:

- Risk retention (absorption)
- Risk reduction (prevention – mitigation)
- Risk transfer
- Risk avoidance

Risk retention or risk absorption is the action of risk acceptance. The party who is aware of the risks and desires to take the responsibility usually applies risk retention. This procedure will eventually load residual risks over the risk retaining party whether it is capable of controlling them or not [33]. In order to compensate the residual effects financially; a contingency sum, which is generally 10% of the estimated base cost, is added onto the base cost. However, this traditional method is inefficient and insufficient unless, risk analysis is performed in detail and realistic solutions are explored. Such scientific solutions naturally increase the chance of the non-occurrence of cost overrun.

Risk reduction (prevention-mitigation) is another way of risk acceptance. It can be achieved by reducing the intensity of risk if it occurs (mitigation) or reducing the probability of risk (prevention) in advance of its occurrence [21]. Training of the staff, physical protection and safety precautions can be useful in a risk reduction operation. Besides, it is necessary to make deep investigation about important risks. Risk retention and reduction is also important in the sense that its degree of success is a factor in determining the amount of insurance premiums. Common risk preventive and mitigative actions of project management are given as follows [14]:

Preventive (at early project stages)

- Utilize quantitative risk analysis techniques for accurate time estimation
- Depend on subjective judgment to produce a proper program
- Produce a proper schedule by getting updated project information
- Plan alternative methods/options as stand-by
- Consciously adjust for bias and add risk premium to time estimation
- Refer to previous and ongoing similar projects for accurate program

Mitigative (during construction)

- Increase manpower and/or equipment
- Increase the working hours
- Change the construction method
- Change the sequence of work by overlapping activities
- Coordinate closely with subcontractors

Risk transfer is the action of transferring the responsibility of risks to another party using a contract, insurance, an indemnity, a bond or a surety [2, 32]. It is a widely utilized risk response strategy but important point to be cared about is that the party to whom the risks are transferred must be capable of controlling and affording the risks. Otherwise, the whole project may be affected negatively.

Risk transfer can be realized through the following routes [34]:

- Client to contractor
- Contractor to sub-contractor

- Client, contractor, sub-contractor to insurer
- Contractor or sub-contractor to surety

Insurance is the commonest form of risk transferring. It is actually the conversion of the risks to a certain value of money. Nevertheless, insurance has some disadvantages. It is the most expensive risk transfer method and disputes occur frequently in case of payment claims. Besides, insurance is only a kind of financial transfer instead of being a complete responsibility transfer. In contrast, as an example, contractual transfer of risks to another party would shift both responsibility and financial consequences to the relevant party.

Risk sharing is another common and special case of both risk transfer and risk retention. Risks are transferred from the individuals to the group by risk sharing. Nevertheless, risks are retained within the group. Therefore, risk sharing is also a kind of risk retention action. An example to risk sharing is the foundation of a corporation. Under this form, a number of investors pool their capital; each is responsible from risks and loss as much as their capital portions in the pool [6].

Risk avoidance is the risk refusing action unlike the risk retention or risk reduction. The best examples are the refusal of the whole project or avoiding only its risky parts. Risk avoidance can be experienced through the following ways [2, 34]:

- Avoiding to bid on the project
- Bidding very high prices
- Using exemption clauses
- Bidding on the less risky portions of the contract
- Ignoring the project (by owner/client)

Risk avoidance is a more consistent and realistic way of risk struggle in fuzzy situations instead of taking unconscious decisions simply for the aim of winning the tender. Investing on different alternatives and projects would be more logical than dragging the company into an adventure if the company did not have enough resources and capacity. Otherwise, terrible events may occur like bankruptcy. However, risk avoidance is experienced to be impractical in many circumstances because "it may lead to projects not going ahead or a contractor submitting an excessively high bid for a project" [39].

A summary of the primary risk sources, possible risk management responses and counteractions are given in Table 2.4.

Table 2.4 Primary risk sources in projects, possible risk management responses and counteractions [11, 40]

PRIMARY SOURCES OF PROJECT RISKS	RISK MANAGEMENT RESPONSES	POSSIBLE COUNTERACTIONS
Design Inadequate design, detail, precision, appropriateness of specifications, surveys and investigations, interaction with method of construction, likelihood of change.	Transfer, Avoidance.	Condition clauses, participation in design, adoptable design/construction methods, revisions of the original design
Environmental Ecological damage, pollution, waste treatment, public enquiry.	Insurance, Transfer, Reduction and prevention.	Contractual clauses, protection and safety programs
Financial and economic Inflation, exchange rate fluctuations, default by sub-contractors and suppliers, availability of funds, adequacy of insurance, adequate provision of cash flow, taxation	Retention, Transfer, Avoidance	Escalation clause, price contingency in the bid, projects financing by a reputable owner, owner's purchase of equipment and material, providing performance bond and pre qualification of sub-contractors and suppliers, forward contracts for hedging exchange rate fluctuations.
Political Changes in laws and regulations, war and civil disorder, expropriation, embargoes	Insurance, Transfer, Reduction and prevention	Insurance, contingency planning, contractual clauses for schedule delays and additional payments, clear contract clauses.
Legal Direct and indirect liabilities, local laws, bureaucratic delays.	Avoidance, Retention.	Contingency planning, contractual clauses
Logistics Availability of specialized resources, access and communications, damage to equipment and material in transit.	Retention, Transfer, Insurance, Reduction and prevention.	Contractual clauses, Purchase including delivery.

Table 2.4 (cont'd)

Construction Climate, industrial relations, different site conditions, defective work, equipment failure and theft, accidents, feasibility of construction methods, extent of change of construction methods	Retention, Transfer, Insurance, Reduction and prevention	Physical contingency in the bid, insurance for liability from accidents, contract clause for time extensions due to delays, safety and training programs for employees, planning procurement activities in advance, quality control and quality assurance programs, application of versatile methods.
Physical Flood, earthquake, fire, collapse and landslide	Transfer, Insurance.	Insurance carried by owner, contractual clauses for delay and payments for incurred damages, contingency planning.
Operational Fluctuations in market demand for output, Maintenance needs, fitness for purpose, safety of operation.	Retention, Insurance, Reduction and prevention	Realistic market forecasts, elasticity of operation, insurance carried by owner.

2.3.5 Risk attitude

Human attitude towards risk becomes an important factor in evaluating the risk analysis results and determining risk response strategies because different people make different decisions within the same risk environment. Besides, the cumulative feature of senior managers' risk attitudes forms the company's risk perception. In a broad sense, there are three types of risk attitude [2]:

- Risk loving
- Risk averse
- Risk neutral

Risk lovers are those who are willing to take additional risks on the expectation of a higher return. In contrast, some are risk averse, unwilling to enjoy the possible higher return even for a relatively small risk. The people who are risk neutral prefer standing at middle.

Researchers have produced utility theory in order to quantify the individual's risk attitude in advance and subsequently forecast his decisions. Utility theory can be defined as a formal approach to measuring the decision-maker's attitude towards risk. Definition of 'utility', in this case, is the satisfaction that the decision-maker receives from given quantities of money. In this context, utility theory becomes a kind of psychological analysis that can be utilized for also managerial purposes in projects. The individual's utility values measured by utility theory can be used in utility-based decision supporting methods such as Expected Utility Value method. Such methods enable making decisions without ignoring risk attitude of the decision-maker. [2].

2.4 Construction risk analysis models

Modeling has been the most frequently utilized method in almost all branches of scientific research. Its power comes from the environment it creates to observe or measure the overall effect of dependent and independent parts of an event over the whole system or structure. Indeed, modeling is a kind of experimental technique. It can be performed through different ways like computer programs, laboratory opportunities or natural means.

Smith [41] describes the model as the abstraction of reality, however, in the sense that it cannot represent all aspects of reality. And he claims that any model should have the three essential characteristics: reference, purpose and cost-effectiveness. In the same way, Rothenberg [42] defines modeling as the cost-effective use of one thing in place of another for some cognitive purpose.

In this manner, risk analysis models can be considered as the organized platforms to assess the effects of risks on the overall project aims. Moreover, they generally become indispensable agents for setting a complete risk management system. The quantitative risk analysis models widely used in construction projects are [43]:

- Cost risk model
- Schedule risk model
- Cash flow risk model

These three models have great importance for assessing the effects of the risks quantitatively and making decisions to struggle against risks in construction projects. It is because the parties involved in any construction project desire the works to be completed within the planned budget and period. Apart from this, the contractor firms aim to make a consistent amount of profit for growing up. Cost risk analysis, schedule risk analysis and cash flow risk analysis modeling help the managers find the strategies to reach the mentioned aims.

2.4.1 Cost risk modeling

Cost risk modeling is a stochastic effort that is exposed to gather the probable risks affecting the construction activity costs, then quantify these effects statistically and transfer all this material to a software environment, and finally run the appropriate simulation or apply the needed analysis technique. The aim of the modeling is to convert all the disorganized data to a suitable form in order to analyze and find the activity-based or production-based total project cost. The total project cost estimated by such a way would naturally contain probabilistic terms instead of being a single value. This leads to more accurate estimates made before the tender by both clients and contractors. However, the classical deterministic technique is still the popular method in estimating project costs: determine the production-related activities and production amounts, multiply the amounts by the fixed-value unit-prices, determine a contingency value and finally add them up. These kind of deterministic approaches are the main causes of not completing the projects within budget because the contractors cannot see the true picture showing the range of which the total project cost differs and eventually they cannot take the appropriate financial precautions or risk response strategies prior to the project.

The typical steps of a cost risk modeling and analysis process are as follows:

- Determine the items that constitute the total project cost (e.g. overhead, construction works, electrical works)
- Determine the amount ranges of these cost items in certain units like m, kg.
- Investigate the cost ranges of these items
- Assign appropriate probability distributions to these cost ranges and amount ranges
- Assign correlation coefficients between the variables (amount and cost) if exist
- Build the mathematical relationship between the variable items through benefiting from the capabilities of the spreadsheet programs like MS Excel.
- Input the simulation preferences through using the capabilities of a risk analysis program like Crystal Ball
- Run Monte Carlo simulation
- Evaluate the results
- Update the model

Cost risk models necessitate a high degree of regional market research regarding the labor costs, material costs, equipment costs and indirect costs. Furthermore, the modeler has to identify the risks and determine how the investigated market costs can change with how much probability. In this sense, a complete model can give logical and realistic answers to questions such as:

- What cost is the most likely project cost?
- In which range does the total project cost change with what kind of frequency values?
- What should be the contingency amount to be added on the traditional deterministic estimate?
- Which cost items affect the total project cost more than others? In other words, where is the risk?

Cost risk models cannot take the time value of money and cost of capital into account unless the necessary regulations (like using foreign currency) are made on the model or the cost estimating is performed in conjunction with the schedule and cash flow calculations. This may not be so important in escalation-paid projects of which the cost increases are paid by the owner for certain cost items. However, it is vital, for example, for fixed-price Design-Build projects especially undertaken in inflationary environments.

2.4.2 Schedule risk modeling

Schedule risk modeling is the other necessary organized analyzing method for construction projects in a case when it is desired to have detailed knowledge about the probable deadline of the project. It is based on activity durations and activity networks just as the conventional schedule planning techniques such as bar charts and CPM. Even though schedule risk modeling operates in more or less the same way, it moreover contains the capability of defining risks in the network's activity durations and network's logical structure [43].

The typical steps of a schedule risk modeling and analysis process are given in Figure 2.10 and further listed as fallows:

- Establish the standard network plan of the project activities
- Determine the three point duration estimates (maximum, minimum, likely) of the activities and lag times
- Assign probability distributions to the risky items
- Set correlations and contingencies
- Construct the network relationships by mathematical formulas
- Adjust the simulation properties on the computer program
- Run the simulation and execute the analysis
- Control the progress and update the model

The two common methods; sensitivity analysis and Monte Carlo Simulation are almost capable of giving the necessary results and for this reason they are the most popular analysis techniques applied in schedule risk modeling.

It is possible to find answers to the questions mentioned below through schedule risk modeling.

- In how much time and with how much probability is it possible to complete the project?
- Which activities are more critical than others?
- Which risks are more effective on the total project duration?

The answers taken to these kinds of questions make the owner, contractor and project manager more conscious about the project deadline before the tender and about the project progress during the project execution. Since the schedule risk models are updateable, they can be modified along the project according to the changing conditions.

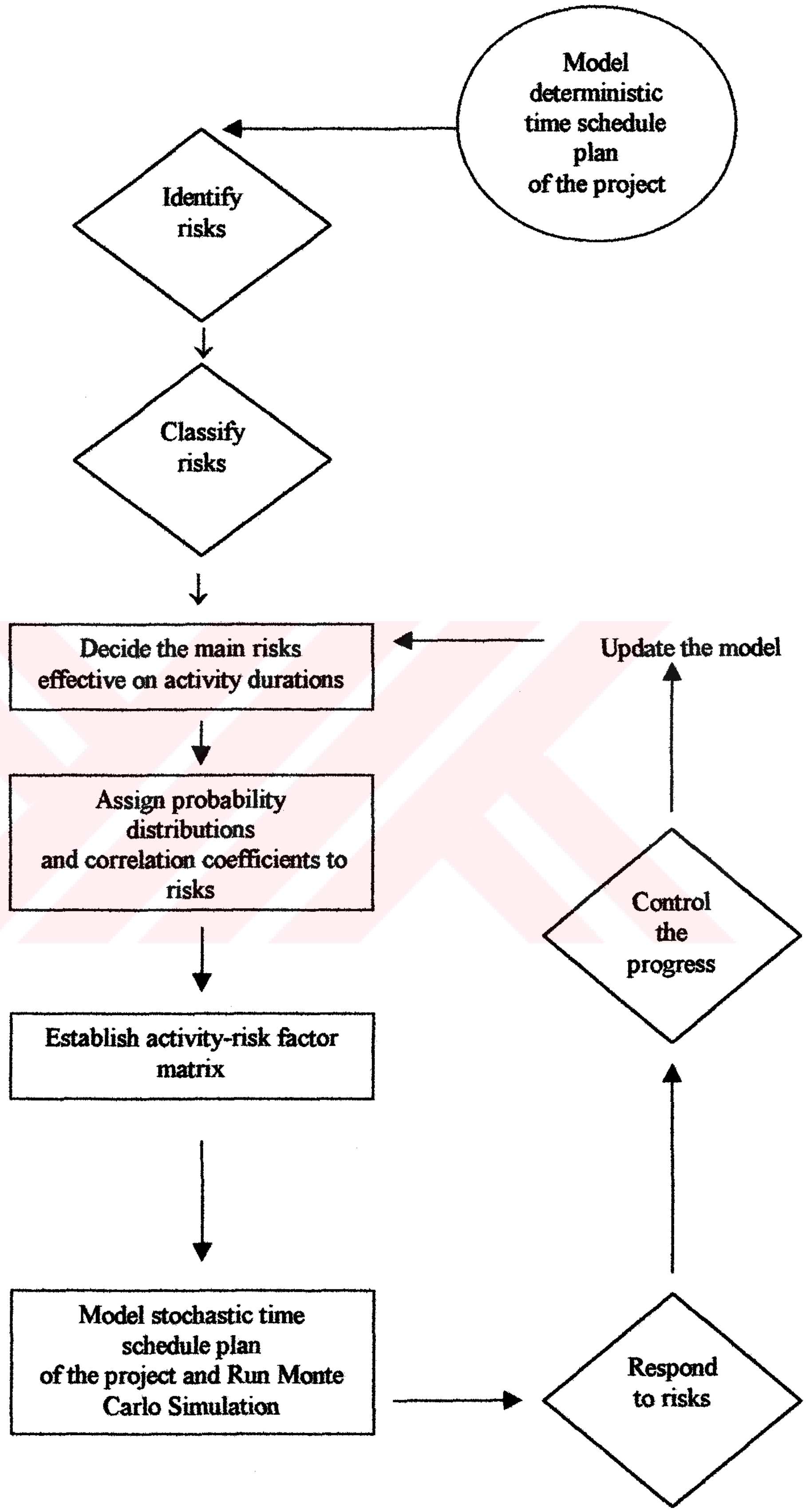

Figure 2.10 Typical steps of a schedule risk modeling process

The activities in construction projects can be classified as production-related, procurement-related and administrative activities. The production-related activities can either be labor-driven or equipment–driven. According to this classification, different methods exist to calculate the activity durations, like heuristics, statistical studies, cycle time analysis, queuing theory and simulation [17]. However, engineering judgment, experience and intuition affect the consistency of the results as in the other risk management steps.

In order to enable Monte Carlo Simulation to calculate the activity durations stochastically within the process shown in Figure 2.10, the following equation (2.1) is proposed after some revision on Dawood' s [44] equation (2.2). This subject is further discussed and then, the proposed method is applied on a case study in Chapter 4.

$$\text{Duration of activity} = \text{MAX}\ [(\text{Min. Time} + \text{Risk Factor Affect}),\ (\text{Max. Time} - \text{Risk Factor Effect})] \qquad (2.1)$$

$$\text{Duration of activity} = \text{MAX}\ [[\text{Min.Time} + (\text{Max.Time} - \text{Min.Time})\ X\ [(RF_1\ X\ \text{Random}_1) + (RF_2\ X\ \text{Random}_2) + \ldots\ldots\ldots + (RF_n\ X\ \text{Random}_n)]],\ [\text{Max.Time} - (\text{Max.Time} - \text{Min.Time})\ X\ [(RF_1\ X\ \text{Random}_1) + (RF_2\ X\ \text{Random}_2) + \ldots\ldots\ldots + (RF_n\ X\ \text{Random}_n)]]] \qquad (2.1)$$

Where;

Min.Time: The minimum duration that an activity can be completed.

Max.Time: The maximum duration that an activity can be completed.

RF_n : The percent effect of n^{th} risk factor on an activity (taken from activity-risk factor matrix)

Random_n : is a random number, between 0 and 1, generated during Monte Carlo Simulation to represent the n^{th} risk factor's probability distribution.

$$\text{Duration of activity} = \text{Min.Time} + (\text{Max.Time} - \text{Min.Time})\ X\ [(RF_1\ X\ \text{Random}_1) + (RF_2 X \text{Random}_2) + \ldots\ldots\ldots + (RF_n X \text{Random}_n)] \qquad (2.2)$$

Deterministic schedule planning (especially bar charts) is almost the only mean used by the parties of construction sector in Turkey. This insufficiency causes the projects to overrun. The total project cost increases in case of overrun and eventually, the reputation of the company is disturbed. Avoiding the schedule overrun is a very important issue in some contract systems especially for the fixed price Design-Build construction projects.

2.4.3 Cash flow risk modeling

Cash flow models are the key tools for evaluating the alternative investments, preparing tender price estimates and controlling the cash movements along the project. Every company or employer institution have to go into detailed investigation about the alternative businesses or projects in order to decide which opportunity is worth undertaking in respect of profit, rate of return, time value of money, opportunity cost and revenues. Cash flow models can also be considered as macro-level project feasibility tools and they are especially utilized prior to the standard project stages for taking strategic decisions.

Cash flows contain the forecast input and output cost values about the investment. Furthermore, the means of cash flow representation like cash flow diagrams and tables create an excellent environment for observing the time of the money movements. The economic value of investigated investment or project is explored by applying traditional economic decision methods on these cash flow figures. Some of these traditional methods are net present value, annual worth, internal rate of return and payback period methods [45].

The same cash flow diagrams and economic decision methods can be used in setting cash flow risk models. The difference of a cash flow risk model from a standard cash flow analysis model is its capability of reflecting the effect of risks and uncertainties on the cash flow items. Sensitivity analysis and decision trees are the two risk analysis methods widely used in parallel with other economic decision methods in cash flow risk modeling [36].

2.5 Computer Programs Used in Risk Analysis

It is almost impossible to perform risk simulations on a risk analysis model without using computer programs. The best example is the Monte Carlo simulation, which necessitates at least hundreds of iterations even for simple models. For this, manual application of Monte Carlo Simulation is inconsistent while computer programs are capable of doing the same job faster, more precisely and with much more running preferences. Furthermore, such programs provide an easy and effective environment for data entrance and worksheet modelling.

There are a number of computer package programs in the market, which can be used for conducting risk analysis. In case of absence of such programs, it is easy for an experienced engineer to set risk models in BASIC or C++. Some of the popular risk analysis programs that can be obtained from the market are @Risk, Crystal Ball, Predict, RISKMAN and Monte Carlo [43]. RISKMAN is mainly a whole risk management software performing almost all the steps of risk management and furthermore, capable of carrying out both qualitative and quantitative risk analysis. Besides the risk analysis and management programs, table processors like MS Excel or Lotus 123 are also used to build risk models. Risk analysis programs also produce excellent reports that can be used at risk response stage of risk management systems and for this reason, they simplify the presentation duties of the project planner to the senior management. Furthermore, such kinds of programs are not expensive and do not occupy too much place on the computer's hard disc.

There are some issues that should be cared of in selecting such programs. These issues are summarized below [43]:

- The program should have the sufficient capability of representing the desired models properly. For instance, some simple programs can perform cost analysis but cannot carry out schedule analysis.
- The program should have correlation power, i.e. it must be able to generate correlated simulations.
- The program should provide an appropriate user interface. The add-in tools that operate on popular spreadsheets like MS Excel are such programs.
- The program's typical running time should not be too slow. Indeed, nowadays' technological level in computer industry already does not permit this.
- The program should have data transferring capabilities from other office and planning programs like MS Excel and MS Project.
- The program should have the capability of making both qualitative and quantitative risk analysis.

The risk analysis programs passing the above points can be considered as sufficient for any kind of risk analysis modeling.

2.6 Risk Management and its Future in the Turkish Construction Sector

Since risk management concept has a narrow past of about two decades in the construction sector and construction management research platform, it would be natural for the Turkish Construction Companies not having wide knowledge and experience on this recent discipline. Gursel [21] has proved this fact in her comprehensive survey carried out for providing information about the current attitudes of leading Turkish construction companies towards risk management. Although the majority of the companies attended to the questionnaire is older than 20 years and can be regarded as big-scaled firms in their field, most of them still have not been aware of the risk management techniques and the small portion that is aware has never used them. Instead, they prefer using traditional methods such as insurance, information gathering and risk contingency amount added to the tender value to cope with risks. However, general risk identification techniques like checklists and brainstorming are widely used. In contrast, none of the contractors uses a computer program for conducting risk analysis.

Obviously, it is not difficult to guess from the above results that hundreds of small-scaled Turkish construction firms are also not aware of any risk management and analysis methods like the other big-scaled companies.

There is also lots of valuable information concerned with Turkish construction companies' risk perception in Gursel's [21] research. Some of the important issues are summarized below:

- The most important market risks are delayed progress payment, insufficient demand in the sector, and possibility of not obtaining long term works.
- The most important political and financial risks are political instability and inflation.
- The least important risks are technical and construction related risks. This result shows that Turkish construction companies are technically sufficient in their fields to undertake complex projects.
- The most frequently occurring risks are high and uncertain rates of inflation. The others are delayed progress payments, insufficient demand in the sector, possibility of not obtaining long-term works, bureaucracy and owner delays.

- The most rarely occurring risks are force majeure, labor strikes, terror, restrictions related to environmental pollution and technical complexity.
- Clients usually allocate the risks onto the contractors by means of contractual clauses. That is, the typical public sector contracts are one-sided. Furthermore, fixed price turnkey contracts are considered as the most risky contract system.

In order to change the above pessimistic picture, the Turkish public owner institutions have to organize structural modifications on their contract contents to make risk management an obligatory activity for the contractors. Of course, this can only be achieved after introducing risk management techniques and tools to the main parties of the sector. Universities and professional foundations may be the leading agents for this duty. It is known that the risk concept and management techniques are not so strange in sectors and industries such as finance, petrol and mining. The increasing complexity, size and competition create the same need in the construction sector.

CHAPTER 3

DESIGN-BUILD CONTRACT SYSTEM

3.1 Introduction

This chapter is organized for the purpose of giving informative background through implementing literature survey associated with the contract systems and payment methods utilized in construction projects. After emphasizing the basic characteristics of these various contract systems and payment types under the light of different classification procedures, the remaining part of the chapter is devoted to the wide explanation of Design-Build contract system. At the end of the chapter, also the point reached in application of Design-Build system in Turkey is discussed.

3.2 Classification of Construction Contract Systems and Payment Types

Different approaches are used for the classification of construction contract systems, although the content and definitions are almost the same. Contract systems, which are also known as 'project delivery methods' or 'project procurement methods', can be simply categorized as 'Design-Bid-Build' and 'Design-Build' [17]. But such a procedure, i.e. classifying the contract methods according to the order of the main tasks of a project, which are 'design, tender and construction', is apparently not enough. Other simple classification types of construction contracts are 'private-public contracts', 'written-oral contracts' or 'negotiation – competition contracts'. Such approaches are also not sufficient to properly describe the various kinds of commitment types undertaken by the parties in the construction industry.

Another categorization of the construction contract systems that stands more complex and accurate with respect to the simple procedures is given below [46]:

- Competitively Bid Contracts
- Stipulated-sum Contracts
- Unit-price Contracts
- Negotiated Contracts
- Design-Build (Turnkey) Contracts
- Construction Management Contracts

Nevertheless, it seems rather complicated to mix payment types and contract strategies like this. For this reason, it would be more appropriate to separate contract systems and payment types. In this sense, construction contract systems are classified as [47]:

- Single Contract System
- Owner Management Contract System
- Construction Management Contract System
- Design-Build (Turnkey) Contract System
- Build-Operate-Transfer (BOT) Contract System

Each of these systems can be further subdivided such as 'Negotiated Design-Build', 'Competitive Design-Build', 'Build-Operate (BO)', etc.

On the other hand, the classification of construction contracts with respect to the payment criterion is as follows [47]:

- Fixed-price (Stipulated-sum or Lump-sum) Contracts
- Unit-price Contracts
- Cost Type Contracts
    - Cost plus fixed fee
    - Cost plus fixed fee with guaranteed maximum cost
    - Cost plus percentage of cost
    - Cost plus incentive fee (or sliding scale fee)

The classification method of contract systems and payment types presented just above will be taken as the base way in giving basic descriptions in the next section. However, there also exist classifications consisting of different terms but more or less having common contents with other classifications. The following list of contract systems and payment types introduces one of these classifications [20]:

- Contract Systems
    - Authority Contractor System
    - Direct Works System
    - Package Deal System
    - The Management System
- Payment Types
    - Fixed-price Contract
    - Cost Reimbursable Contracts
    - Admeasurement Contracts (Bill of quantities, Schedule of rates)
    - Target Contracts

3.3 Description of Construction Contract Systems and Payment Types

Brief descriptions of the above contract systems and related payment types are given below, except for the Design-Build, which will be gone through widely along the next sections:

- Contract Systems:

Single Contract System: is a traditional form of contract system in which the construction is under the responsibility of a general contractor and subcontractors who are under contract to the general contractor.

Owner Management Contract System: is another widely used system especially by large public agencies that have their own work force and for this reason, place themselves in the position of a construction management firm and coordinate all the construction through awarding different parts of the site activities to different specialty contractors under separate contracts.

Construction Management Contract System: is a popular system recently having been increasingly used in large projects. The owner generally utilizes this system through negotiation. The construction management contractor is expected to be perfectly qualified to manage all the construction on behalf of the owner.

Build - Operate - Transfer (BOT) Contract System: The Build-Operate-Transfer contract system is a method of private sector project financing. A company under private ownership or a joint venture with a minority of public participation is established to plan, finance under limited resource, design, construct and operate the facilities for a concession period before the facility is transferred to the government [48]. The aim of this system is to encourage the private sector and foreign capital to invest in sectors such as energy, transportation and infrastructure.

- Payment Types:

Fixed-price (Lump-sum) Contracts: The contractor is responsible to complete the entire project at a contracted fixed price in this payment type. This price never changes whatever the actual cost of the construction is at the completion. However, some arrangements can be made regarding the fixed price according to the contract clauses about some risks such as unforeseen ground conditions. This payment type is attractive from the viewpoint of the owner because he/she gets aware of how much the project will cost prior to the start of the construction. In contrast, it is very risky for the contractor if the scope and content of the project is not well defined prior to bidding.

Unit-price Contracts: This type of payment method allows change in the contract price to some extent in case of the additional work that has not been predicted at the preliminary design and planning stages. The payment certificates are prepared periodically and at fixed costs per units of work completed if there is no cost escalation. It provides the owner more flexibility in case of probable changes related to the scope of the project and more control on the activities performed at the construction site.

Cost + Fixed Fee Contracts: The owner pays the cost of the entire construction and in addition a fixed fee to the contractor, whatever the actual cost of the project appears to be at the end.

Cost + Fixed Fee with Guaranteed Maximum Cost: The owner agrees to pay the entire construction cost and a fixed fee to an extent that the total amount including fee and cost is guaranteed by the contractor not to exceed a maximum amount. Otherwise, the contractor pays the additional cost amount.

Cost plus percentage of cost: The owner pays for all costs and a fee determined on a percentage of the total construction cost. This type of payment is advantageous to the owner in case he/she desires the job completed quickly. However, it is open to abuse if cost control is not taken into account by the contractor on behalf of the owner throughout the construction.

Cost plus incentive fee: The contractor is paid for all costs and a variable fee in addition. A target cost and target fee are determined in the contract; in case the actual cost of construction is less than this target cost at the end, the fee increases at the amount equal to the remaining part of the target cost. This situation provides an incentive for the contractor to minimize the costs to earn an increased amount of fee in accordance.

3.4 Selection criteria of Construction Contract Systems and Payment Types

The selection of the appropriate contract system in case of the procurement of a construction project is vital for the sake of successful delivery of the job. The decision about this critical selection depends on several factors such as available time, complexity of the project, cost requirements, price uncertainty, desired flexibility in making changes, risk allocation, political stability and etc. [49]. Except for these factors, owner requirements and end-user's needs are also crucial and should be taken into account.

In some projects, the utilization of more than one payment type is possible for different parts of the same project. For instance, payment can be made simultaneously on fixed-price and cost plus fixed fee basis in a construction project contracted upon Design-Build system. In other words, the payment type of a contract system may be modified from fixed price to unit price and finally to cost plus in case the risk increases on the whole project or in different parts of it [50].

Turner & Simister [50] claim that there are four parameters that should be considered in case of choosing the suitable contract payment type:

- Complexity of the project

- The ability of the owner to contribute to the resolution of problems
- Uncertainty of the product
- Uncertainty of the process

For example, as the uncertainty of the product and process is low enough, unit-price contracts are appropriate. If the product is certain, but the process is uncertain, fixed-price (even fixed-price Design-Build) contract is preferred. Finally, if both of them are uncertain, cost plus contracts will be more suitable.

3.5 Design-Build Contract System

It is known that nowadays, an increasing number of projects are being contracted based on Design-Build or Turnkey system in the construction sector, instead of using other classical contract methods [49, 51-56]. Then it is worth discussing this new popular contract system, setting its definition, investigating its advantages and limitations and emphasizing its application areas.

3.5.1 Definition

Design-Build can be defined as a contract system in which one contactor, firm or consortium takes full responsibility and carries sole liability for both design and construction [49]. A comprehensive definition of Design-Build has been made by the CIOB (The Chartered Institute of Building) as follows:

The client deals directly with the contractor for the complete building and it is the contractor who is not only responsible for, but also coordinates the separate design and construction processes, including engagement of the design team who are, therefore, contractually linked with the contractor and the client. The construction process, whilst linked, is still separate from the design process, leaving the consultants free to concentrate on their own roles. The client may, however, directly appoint either in-house staff or a separate consultant to check that the product the contractor is providing is value for money and that content and quality are satisfactory [57, 58].

In this context, while Design-bid-build and Construction management contract systems mainly contain three parties (designer, owner, builder) and four parties (designer, owner, construction manager, builder(s)), respectively; Design-Build, in contrast, offers two main parties' direct involvement to the contract: owner (client) and design-builder. This situation simplifies the project execution and increases the project success level because a single firm (joint venture, consortium or design-builder in general) undertakes the responsibility of both designing and building. "With both design and construction in the hands of one entity, there is a single point of responsibility for coordination, quality, cost control, and schedule adherence, which avoids blaming others for errors and shortcomings" [54] (p.2). This converts the effort of the owner to the scope and progress of the project instead of consuming it through strict debates and coordination issues between design team and contractor as in the case of Design-bid-build and Construction management contract systems.

3.5.2 History

The history of Design-Build begins with the ancient civilizations of Egypt, Greece and Rome in spite of the fact that it is a new concept in the modern construction world. For instance, the Code of Hammurabi (1795-1750 B.C.) known as the first written public rules in history contains codes about the responsibilities of a builder who must design and then build [54]. In 1970s, Design-Build was being applied in private industrial construction projects such as petroleum refineries and chemical process plants due to the complexity inherent in these projects and strict time requirements. However, especially for the past decade, Design-Build contract system has also been used widely in public and private building construction sectors [17]. Design-Build has evolved as an alternative contract method to traditional Design-bid-build and Construction Management systems since 1970s and it has started to be used extensively by 1990s in both private and public construction sectors of the developed countries [54].

3.5.3 Advantages and disadvantages

The advantages of Design-Build contract system can be summarized as follows [17, 32, 46,47, 49, 54, 59]:

- Project duration is shortened
- Guaranteed cost of construction and date of completion is offered by contractor
- Coordination between design and construction is enhanced due to the fact that design and construction departments are the sections of the same firm and they work in collaboration.
- Design and construction can be carried on concurrently
- There is a chance for the arrangement of a single contract for the total project, if no sub-contractors are employed directly by the owner
- Less disputes and claims occur
- Quality increase
- Cost saving
- Reduced administration
- Early knowledge of costs

- Best-value selection
- Single point of responsibility
- Cost effectiveness
- Innovation encouragement
- More profitable than non-design/build projects

Design-Build contract system has also disadvantages and limitations. They are listed below:

- Final design quality may be poor
- Lack of certainty exists regarding with expected performance
- Tendering costs are high (esp. from contractors' viewpoint)
- There is lack of flexibility in case of owner's changes during construction
- Value for money, and owner satisfaction are not guaranteed
- Owner has often little or no independent supervision of the works on construction site. This may cause quality decline and long-term annual maintenance costs increase.

Quality increase occurs due to the increasing responsibility of the contractor (design-builder), i.e. the increasing responsibility creates further motivation for the design-builder to catch the desired construction quality level so that the risk of performance failure is avoided. Next, the action of design team and building team as a single body inevitably prepares an environment for evaluating and comparing alternative design and construction procedures in coordination and this leads to optimum solutions and so *cost savings*. Another positive point, *time saving* is generated by overlapping of design and construction, i.e. construction begins before the design is completed and both is realized simultaneously through the project. Besides, *administration effort* of owner is reduced in Design-Build, because there is a single contract. Another advantage of Design-Build, particularly for the design-builder, is its capability of showing construction *costs early* in the design development phase because of the direct coordination of design team and construction team in a single body. The next advantage and superiority of Design-Build can be observed when evaluating and selecting the *best proposal* among the proposals of competing firms. Design-Build proposal selection methods allow the owner to compare the scope and quality of the proposals with their offered prices. In other words, the owner does not simply select the lowest cost as in the case of traditional DBB competitive tender. For instance; weighted criteria, emergency, adjusted low bid, stipulated sum/best design are some of the proposal evaluation and selection methods utilized in DB tenders [54]. The appropriate procedure among these is determined according to the project conditions, applicable laws and regulations. *Single point responsibility* is probably the main advantage of DB. Less the number of responsible parties, less the problems encountered. This peculiarity leads to another two important characteristics: *cost effectiveness* and *lower disputes*. The last advantage of DB is its *innovation encouraging* character. Since the owner as in the case of Design-bid-build and Construction management does not transfer the orders from a separate design team to the contractor's construction team, innovative solutions are produced in Design-Build with the parallel working environment and strict coordination of both teams.

The main advantages of Design-Build discussed so far create further profits such as [58]:

- Less interest payment
- Quick utilization of capital (for owner)
- Avoidance of market uncertainty (for owner)
- Less impact of inflation
- Better value for money
- Minimization of risks (for owner)

All of the above advantages and profits build a sound infrastructure for the application of Design-Build contract system and makes it an excellent solution for many projects of construction sector. However, the contractors of the developing countries like Turkey, because of the following reasons, may resist this new and modern contract system at the beginning:

- Weak design capability of contractors
- The uncertainty due to the lack of experience
- High tendering costs, especially for local contractors
- Difficulties in cost and time estimating
- Increased necessity to quality control especially for the public works

3.5.4 Types of Design-Build contract system

There are two main types of Design-Build contracting method: Negotiated Design-Build and Competitive Design-Build. In case of a Negotiated Design-Build, the contractor or consortium is determined after a negotiation with the owner. No competitive bidding is arranged. The owner generally has sufficient information about the negotiated contractor's expertise and success level from his/her previous jobs. However, this type of Design-Build is generally offered by private sector owners. On the other hand, Competitive Design-Build is frequently preferred among public sector owners. In this type of Design-Build, several firms are invited to the competition and generally, the firm that offers the least price wins the tender. The tenders are prepared based on the outline design produced by owner 's consultant engineers. Figure 3.1 illustrates the steps of a classical Competitive Design-Build process.

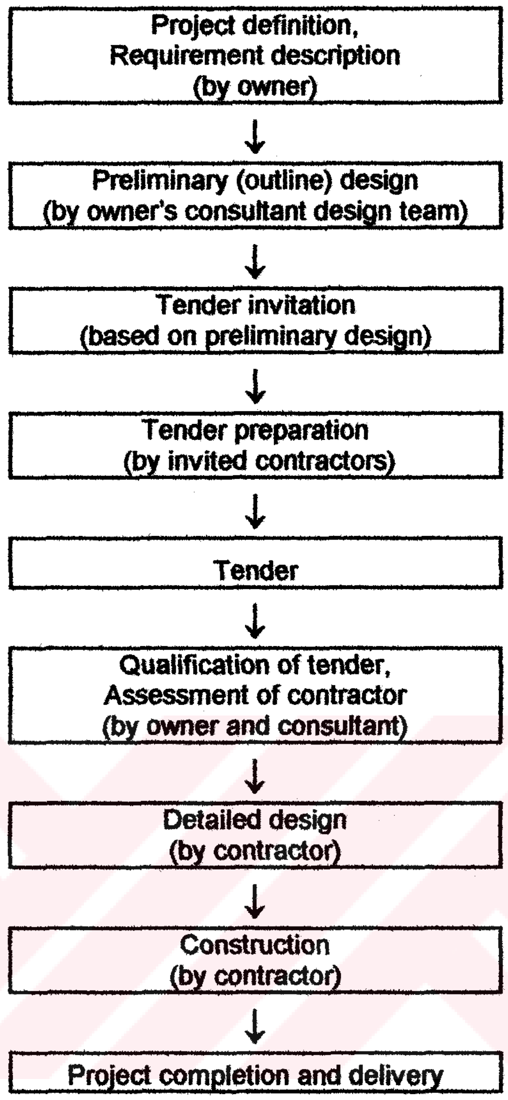

Figure 3.1 The steps of competitive Design-Build process

Nevertheless, researchers have produced alternative process models in order to overcome shortcomings of classical Design-Build contract system. Different techniques such as concurrent engineering are being used for the development of these alternative models. One of these models is shown in Figure 3.2 [49]. A model like this may be capable of identifying owner requirements clearly at an early stage, developing outline design quality, decreasing delays and disputes, decreasing project uncertainty, enhancing team working and group dynamics, and increasing construction quality.

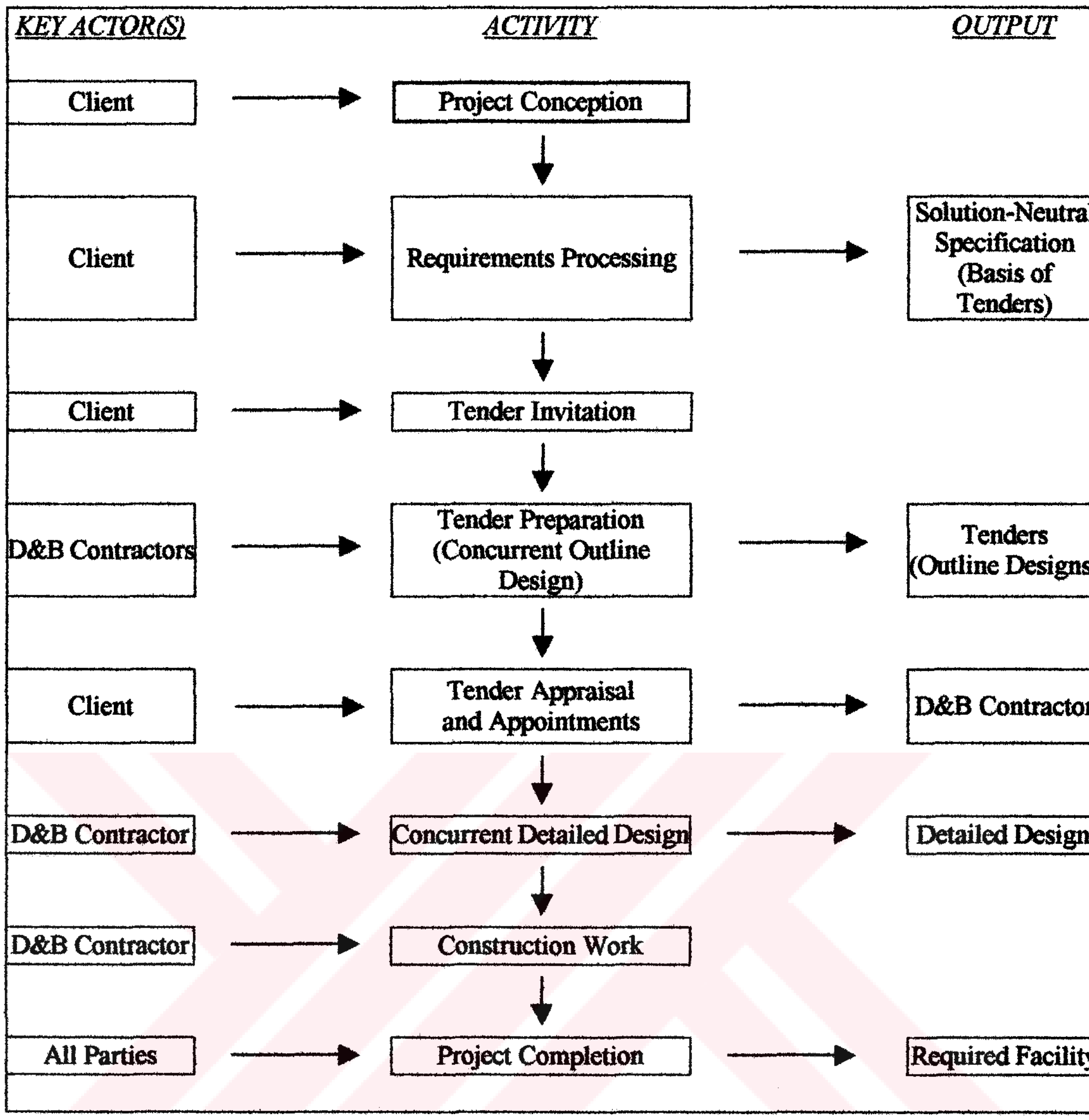

Figure 3.2 New Design-Build process model [49]

There is also another classification type of Design-Build except for the negotiated-competitive separation that is described above. In fact, negotiated-competitive type of classification of Design-Build is in some sense characterizing the system according to the tender awarding method, which is negotiation or competition. However, it is also possible to classify the Design-Build contract system with respect to the amount of design information provided by the owner prior to the tender. The details of this classification is summarized below [60]:

- Develop and Construct: The owner provides the schematic design to the contractors instead of providing detailed design. In other words, the contractors are not free to propose completely their own designs. Instead, they are responsible for ensuring structural sufficiency, method of construction and other special requirements. Civil engineering, building and housing projects are all appropriate works for applying Develop and Construct system.

- DB-single-stage tender: The owner provides the outline design to the contractors. This system can be applied in projects where design and construction facilities are quite standard.
- DB-two-stage tender: The owner provides only sketch plans showing the building layout. Therefore, the first stage of the tender consists of the evaluation of the design proposals prepared and submitted by the contractors. At the end of the first stage, three contractors are selected and the others are eliminated. These three contractors in turn develop their previous design proposals, find out their bid prices, prepare schedule programs and enter to the second stage of the tender. Finally, the successful contractor is selected at the end of this stage.
- Turnkey approach: In case of turnkey approach, owner does not provide any design information. The contractor is fully responsible for undertaking all the works from inception to the construction of the project. It may also include the site acquisition, financing, leasing and personnel training. This method is suitable in projects where special experience is needed.

3.5.5 Design-Build payment methods

There are four types of payment methods frequently utilized in Design-Build contracts: fixed-price (lump-sum), cost-plus, guaranteed maximum price and unit-price [54]. These methodologies can be utilized separately along a whole contract or can be utilized in combination within a single contract at a certain order. This order is determined in relation with the progress levels of design and construction processes. For instance, a logical order can be; first, cost plus, then guaranteed maximum price and finally fixed-price as the design and schedule are developed and clarified in further detail through the project progress. In addition, unit prices can be used at each of these steps, particularly for specific portions of the work.

Fixed-price payment methodology is appropriate when the owner is able to submit a sufficiently detailed program and preliminary design to design-builders for their understanding of his/her needs and requests. ("The American Consulting Engineers Council has recommended that the design be approximately 35 percent complete prior to bidding for a design-build contract" [17] (p.75)) However, this is a disputable issue for the reason of its possible decreasing effect over the design creativity of the design-builder. The AIA (American Institute of Architects) contract forms offer two step contracting strategy to cover this handicap: The first step contract contains a fixed price submitted only for design and if the owner accepts the detailed design, the schedule and the proposal at the end of the design development period, the second part of the contract is signed up, which includes a fixed price of the construction.

In fixed-price contracts, progress payments and related issues can be arranged according to the benefits of both owner and design-builder. For example; payments can be made at specific intervals, the retention value can be lowered or discontinued after a percentage completion, or a schedule of values can be used for determining percentages of completion of different parts of work.

One of the main benefits of fixed-price contract method for the owner is that it does not require the owner to analyze the cost records of the contractor. This easiness also lowers the accounting expenses for both parties.

The other methodology cost plus (or cost plus fee) is appropriate when the project definition and programming is difficult to be made before the execution and related to this, when design-builder is selected through negotiation. Cost plus contracting turns to be disadvantageous in case the owner's estimated budget is exceeded by the design-builder because of uncontrolled and uncared expenses. In this sense, it is a risky procedure for the owner. In standard cost plus Design-Build contact forms, the reimbursable and non-reimbursable cost items by the owner are clarified in detail so that the parties become available to arrange and control their budgets. For example, capital costs and costs due to the negligence of the design-builder are not reimbursable typically in all standard contract forms, whereas construction site overhead costs are generally reimbursable.

A disadvantageous side of cost plus Design-Build contract is its complex progress payment procedures, i.e. the costs are paid as they are incurred and billed by the design-builder. This inevitably increases the accounting works.

Cost plus with a guaranteed maximum price methodology is, in fact, a combination of cost-plus and fixed-price, and they are utilized in case the owner has finite resources to commit to a project. It is a financially beneficial strategy for both the owner and design-builder, when the actual cost of the project does not exceed guaranteed maximum price. If so, the savings are contractually shared and this creates an incentive for the design-builder to manage better. Nevertheless, the owner's needs and requests (owner's program) should have been well defined and design should have been developed up to a sufficient level in order the parties to negotiate on a suitable guaranteed maximum price.

Unit prices are frequently utilized in Design-Build contracts when the actual quantities of unit construction items cannot be forecast accurately before the contract. The reason for this is that unit prices allow adjustment in case the quantities are exceeded. In addition, unit prices can be used as an aid for specific portions of a cost plus or fixed-price contract, which cannot be defined in advance.

3.5.6 Application areas of Design-Build in the construction sector

"Practitioners of Design-build have recognized that the design and construction industry is driven by owner needs" [54] (p.57). This means that as far as the needs and requests of the owners are investigated and expressed professionally, Design-Build becomes the ultimate solution for various markets of construction sector. Furthermore, the size and complexity of projects do not affect the applicability of Design-Build [56]. The main application areas of Design-Build Contract System are listed below [54]:

- Power producing facilities
- Water and wastewater treatment plants
- Food processing plants
- Bulk material handling facilities (e.g. coal handling)
- Disposal facilities
- Transportation facilities (e.g. roads, culverts, bridges, highways, airports, retaining structures)
- Civil infrastructure projects (e.g. drainage, drinking water, rainwater pipe systems)
- Buildings (e.g. school buildings, hospital buildings)
- Military facilities
- Computer and telecommunication facilities

The success of Design-Build deliveries are dominantly dependent on the proper and complete definition of the owner needs in terms of quantity, quality, budget, operation, capacity and schedule. Therefore, owners frequently employ experienced program specialists for this task before tender and after this, competition method becomes suitable for proposal evaluation and selection. However, negotiated or direct Design-Build turns to be more appropriate in case the owner is not available to define the needs and requests in detail. Figure 3.2 is an illustration of a Design-Build methodology that can be utilized in such cases. It is clear that early participation of the design-builder(s) to the program definition process is necessary and unavoidable if the needs cannot be defined by the owner in detail prior to the tender stage.

3.5.7 Participants of Design-Build projects

In minimum conditions, there are only two parties acting in Design-Build projects: owner and design-builder. Design-builder is responsible and accountable for his commitments written in the contract. In other words, owner and design-builder can be considered as the primary participants of any Design-Build project. However, complex Design-Build contracts necessitate third parties for the sake of achieving the desired objectives of the project. These participants are given with their brief descriptions below and further illustrated in Figure 3.3 [54].

- Owner's team
    - Representative: Representative is a consultant empowered by the owner to implement the project and is responsible for ensuring that the project meets the organization's objectives.
    - Design criteria professional: Design criteria professional is in a position of clarifying the interests of the owner in objective and quantifiable terms so that design-builders can understand the owner's requests.
    - Design professional accomplishing preliminary design: Design professional is employed by the owner for preparing preliminary design and evaluating the design proposals submitted at tender by the invited design-builders. For this, the preliminary design prepared by design professional is submitted to the invited design-builders before tender for their usage throughout the proposal preparation.

- Construction manager: Construction management team may be employed in case the technical capabilities of the owner's staff is not sufficient to control the construction site and progress of the project.

- Design-builder's team

  - Design professionals: Design professionals of design-builder are responsible for preparing the design in sufficient technical detail, according to the owner's program and preliminary design.

  - Constructor: Constructor acts as the agent responsible for realizing the construction at site according to the developed design.

  - Subcontractors: Design-builder may hire subcontractor firms for realizing the parts of the construction that necessitate special expertise such as heating, ventilating, air conditioning (HVAC) system and structural steel fabrication and erection.

  - Material and equipment suppliers: Material and equipment suppliers must act as a team member of design-builder in order to understand the project needs and produce quick and proper solutions.

- Independents

  - Quality assurance professionals: They can be employed by design-builder to assure the quality level mentioned in specifications and drawings from the beginning of construction till the end or they can be employed by the owner, especially at the end of the project during commissioning, for testing the performance capabilities of the finished facilities.

  - Building officials: They are public (state) institutions and independent organizations permitting and reviewing the project facilities from legal and technical viewpoint. Local authorities, state directorates, engineering and architectural associations are some examples of these institutions.

- Users: Users or customers are those who use and benefit the facilities or structures completed by design-builders. Therefore, their thoughts and needs should be analyzed and taken into account by both owners and design-builders prior to the project.

3.5.8 Organization and management of Design-Build projects

Design-Build projects consist of members from various disciplines and experiences as shown in Figure 3.3. Associating all these different characterized individuals within a team (design-build team), organizing them through assigning responsibilities, and shortly managing of all these individuals, parties and other resources (materials, equipment, money, etc.) are of the key success factors of these projects. Since Design-Build is a collaborative phenomenon of two main parties agreed upon a single contract and this contract holds all the parties together around the interest of common project goals, it is inevitable for the project success to be dependent on a team that will work harmoniously and efficiently to achieve these shared goals. The project size and complexity, the single point of responsibility and shared goals are the main factors that affect the organizational structure in Design-Build projects. Furthermore, the needs and motivations of the team members consist of common points, but also different points which should be recognized and satisfied in order to protect the team's harmony and efficiency.

Common needs that motivate team members may be physical (shelter, rest) and biological (food) needs; security needs, societal needs (acceptance, friendship, sense of belonging to a larger organization) or related to self-esteem (pride, self-confidence, status, ego) and self-actualization (continuing to seek further development of one's potential) [54]. The duty of organizing and managing the parties, individuals and resources in a Design-Build project belongs to the design-builder or his representative, Design-Build Project Manager. The primary responsibilities of a Project Manager in Design-Build undertakings can be summarized as follows [54]:

- Understand and define the scope and objectives of the project
- Develop and communicate a strategy for managing the project
- Establish and mobilize the project team
- Create and implement project operating procedures
- Plan and control budget, schedule and quality
- Coordinate, communicate and execute the work
- Administer changes, direct personnel and solve problems
- Maintain safety
- Exhibit maturity and a sense of humor
- Satisfy the owner

The parties involved in design-builder's team under the management of design-builder (project manager) should agree on different issues, in advance, that would probably create problems and disputes later. This agreement may be an informal letter or a formal covenant, but it is independent of the contract signed between the owner and design-builder. The risk of proposal development cost can be given as an example to such problematic issues; that is the owners rarely reimburse the proposal development costs of design-builders, therefore allocation of the consequences of this risk among the team-members (designer, constructor, construction manager, etc.) should be determined in advance of deciding to attend to the design-build competition.

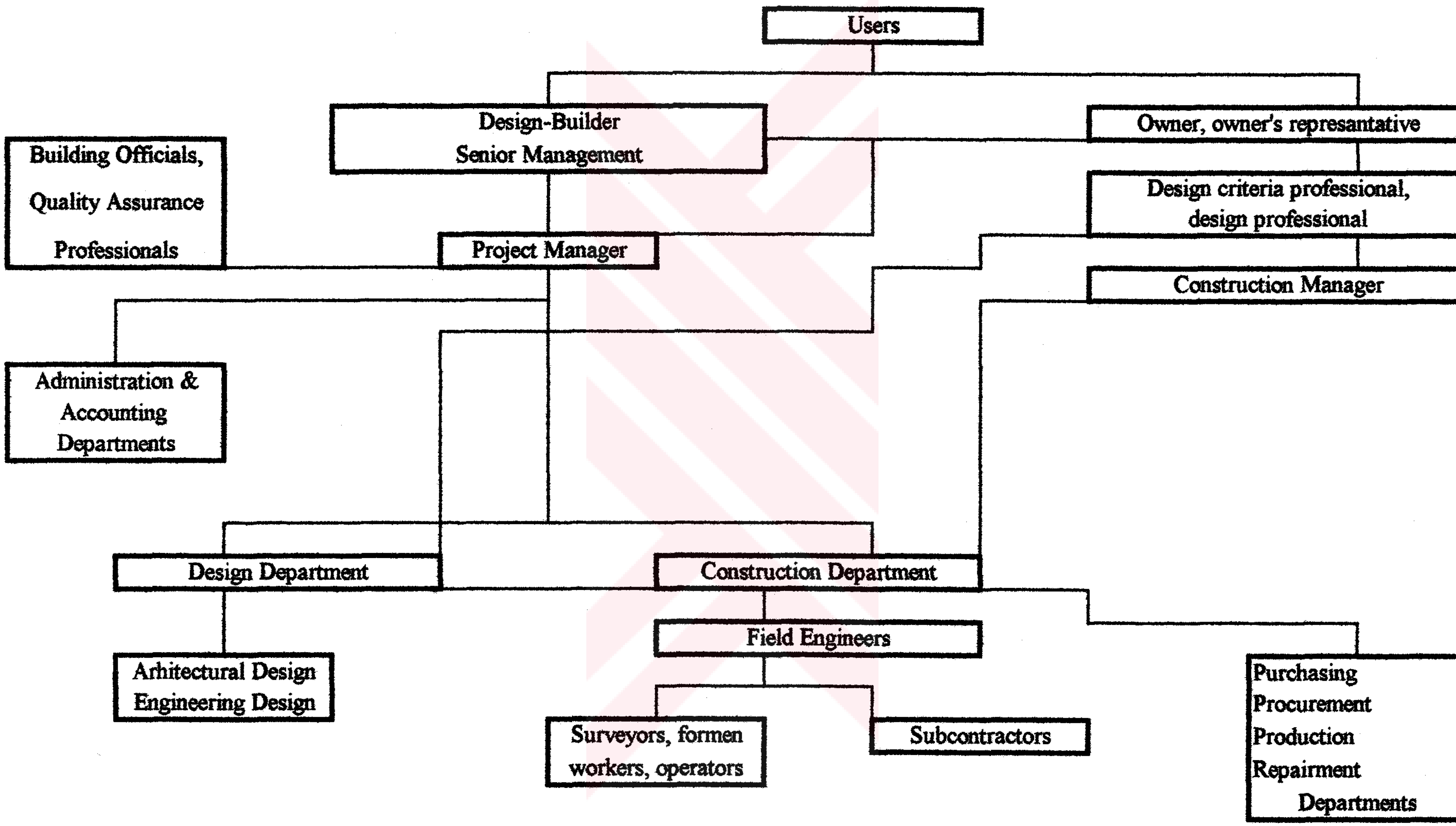

Figure 3.3 Design-Build project organization

The project manager of a design-build organization has to manage both design and construction processes. However, he would have to manage only design or construction if the project was a Design-bid-build or Construction management. In order to control such a big and complex entity, the manager is in a position of utilizing all the management skills and methods currently available in modern management literature. These main skills and methods can be summarized as below:

- Planning and scheduling
- Cost estimating
- Time management
- Cost management
- Subcontract management
- Organizing
- Controlling and updating
- Change management
- Safety management
- Risk management
- Material and equipment management
- Quality management
- Performance management

Risk management is one of the key items among the above managing tasks because it is more or less related to all other project dimensions. However, the most critical and important tasks are planning, scheduling, estimating and cost management. A risk management system integrated with these critical tasks naturally becomes the milestone of the project success.

3.5.9 Standard contract forms of Design-Build contract system

The purpose of a project contract is to create a cooperative project organization, in which all participants are motivated to achieve common objectives [50]. As Design-Build has become a popular contract system of the last ten years in national and international construction sectors, particularly in developed countries, several authoritative organizations have developed standard forms of Design-Build contracts. The identities of main organizations and their products are described below [54]:

- DBIA (USA, Design-build Institute of America): DBIA published the DBIA Contracting Guide in 1997 for the purpose of providing guidance to owners, design-builders and other participants about the critical issues between the owners and design-builders in a design-build process. The contracting and payment types proposed within DBIA Contracting Guide are, respectively, negotiated, competitive, fixed-price and cost plus with guaranteed maximum price option.
- AIA (USA, American Institute of Architects): The standard forms of contracts published by AIA in 1996 are AIA Document A191, B901 and A491. The proposed contracting is the negotiated type. However, no payment strategy is strictly mentioned in AIA documents.
- EJCDC (USA, The Engineers Joint Contract Document Committee): The design-build family of documents published by EJCDC in 1995 is EJCDC 1910-40, 1910-48, 1910-42 and 1910-43. These contracts propose the competitive process as the contracting method, and fixed-price and cost plus with GMP option as the payment methods.
- AGC (USA, Associated General Contractors of America): AGC released its first documents in 1994. Their code names are AGC 400, 410, 415, 420, 450, 460. Both negotiated and competitive contracting types are proposed in AGC standard form of contracts. Besides, the proposed payment types are fixed price and cost-plus.
- FIDIC (Switzerland, International Federation of Consultant Engineers): The design-build production of FIDIC is the Orange Book (The conditions of

Contract for Design-Build and Turnkey). It was published in 1996 and has been widely used internationally since then.

- JCT (UK, Joint Contracts Tribunal): JCT has been publishing the editions of 'JCT Standard Form of Building Contract with Contractor's Design' since 1981. It has been used throughout the United Kingdom.
- ENAA (JAPAN, Engineering Advancement Association of Japan): ENAA published a new form of contract in 1996 for design-build power-plant construction. It is often used on World Bank power projects.

There is no Turkish version of standard form of Design-Build contract that is produced by an independent engineering/architectural or consultant institution. Some state agencies have used their own specific contracts adjusted according to Design-Build system in their limited number of Design-Build projects. Nevertheless, the representative institution of FIDIC in Turkey, the Association of Turkish Consultant Engineers and Architects (TMMMB), has translated design-build FIDIC form of contract to Turkish for its general use [61].

The advantage of utilizing standard Design-Build contract forms is that "they provide an economical and convenient way for parties to contract without having to resort to expensive lawyering to create a contract for each new project" [54] (p.347). Moreover, these forms can be used with little modification if necessary and their content provides similar legal platforms for similar disputes in different projects. However, great care is necessary for their application because every Design-Build project is unique and so may have specific characteristics.

3.5.10 Risks and Design-Build contract system

Already existing risky environment in construction projects turns to be more evident and effective in case the project contract system arranged is Design-Build. In other words, Design-Build is one of the most risky project contract systems in the construction sector. However, the level of risk allocated to the parties in a Design-Build process greatly varies with respect to the payment type executed within the project. For instance, a great portion of the risks is transferred to the contractor in case of fixed-price payment form whereas the owner is in a more relaxed position. On the other hand, cost plus payment forms may be more risky for owners. For example, cost plus fixed fee becomes very risky if the contactor doesn't concern about the construction costs on behalf of the owner. Different kinds of cost plus payment forms have been offered by owners in order to overcome such shortcomings. As an example, cost plus fixed fee with guaranteed maximum cost happens to be less risky for the owner when compared with cost plus fixed fee type. Figure 3.4 gives a schematic representation of the risk proportioning issue between the owner and contractor according to the payment type of the Design-Build Contract.

Time, quality and operation requirements are other three areas that are affected extensively from risks in construction projects. It is a fact that one of the main reasons of an increasing number of private and public sector owners of developed countries having used to offer Design-Build is that the contractor promises for a guaranteed completion date, quality level and operation capacity. In this sense, earlier completion of the project as much as possible would be profitable and advantageous both to the owner and contractor. Therefore, risks that may confront with achieving time, quality and operational goals of Design-Build undertaking have to be identified and managed properly in order to avoid disastrous results.

Risks inherent in any construction project are allocated between the owner, the design team, the general contractor, the specialist contractor, and the material and component suppliers in various contractual relationships [2, 20]. In contrast, any Design-Build contract form has a different structure from classical contract types. This difference affects the risk allocation between the parties.

There are two main parties in a Design-Build contract: the owner and the Design-Build contractor. Design team has already been a member of the contractor's firm. In other words, design team has no contractual relationship with the owner separately. In the same way, specialist contractors and material suppliers are liable only to the Design-Build contractor. Success or failure of these secondary parties is not the concern of owner. In a Design-Build job, the owner negotiates only with the Design-Build contractor and desires him/her complete and deliver the project in time, within budget, and in compliance with quality specifications and operational needs. He/she is the Design-Build contractor who faces with the other parties inside and outside of his/her firm in order to achieve the contractual goals.

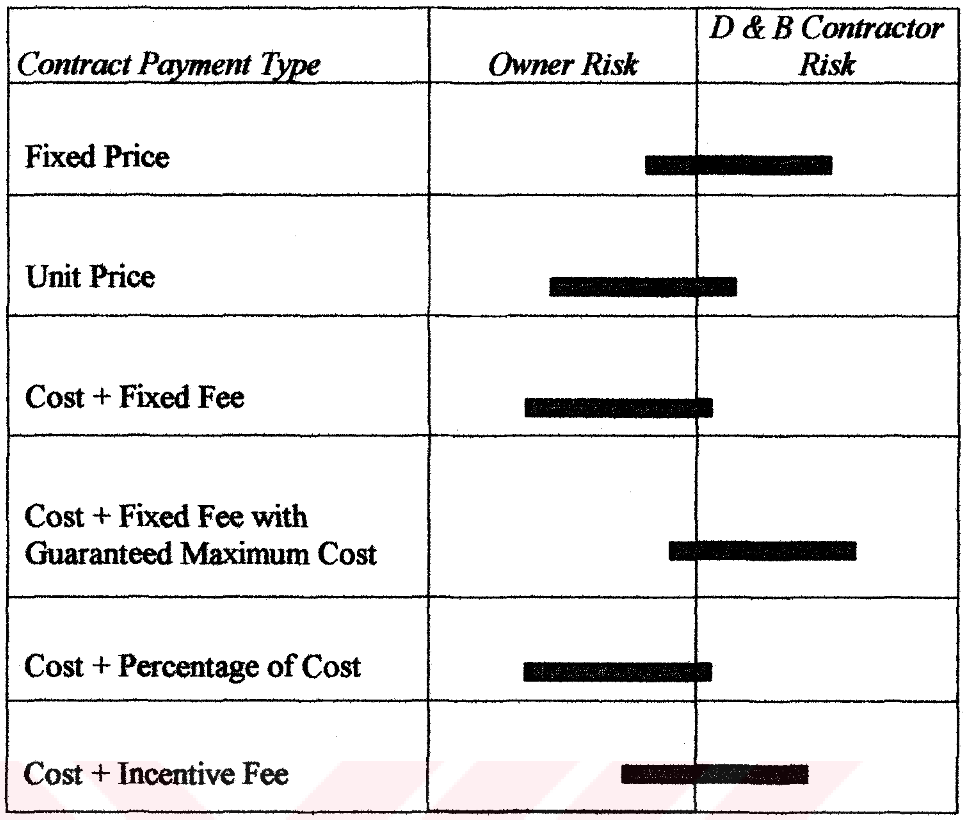

Figure 3.4 Risk distribution between parties in Design-Build contract system

The probable risks in a Design-Build contract system affect the following aspects of the project:

- Design adequacy
- Construction cost
- Safety
- Completion deadline
- Quality
- Operational adequacy

In order to manage risks and hold the success regarding the above items, risk management and analysis tools become indispensable in Design-Build construction projects. Owner's design consultant can use risk identification and analysis tools for establishing owner's requirements while preparing the outline design prior to the tender. In the same way, Design-Build contractor may use risk management tools while preparing for his/her tender and may set up risk management system during the construction phase to control the main project risks and liabilities.

The tendency in traditional construction contracts is shifting almost all of the project risks to the contractor. The philosophy lying under this procedure is the thought that the contractor has to accept the potential risks in return of the appropriately adjusted profit. By the time, it is recognized that this unbalanced risk allocation strategy is wrong because it was leading to contractors' unrealistic tender proposals and disputes. Furthermore, these problems were preventing the parties from reaching the project aims regarding with cost, time and quality.

The Construction Industry Institute of USA (CII) has published a report on the contractual risk allocation issue after the conduction of forums at the last years of 1970s. The main concluding remarks of the report is as follows [62]:

- The most cost effective contract is the one that assigns each risk to the party that is best capable of managing and minimizing that risk.
- The traditional approach of shifting the risk to contractors, who, in return, shift it to subcontractors, is not the right procedure of risk allocation. The true trend is assigning the risk to the party that can control it best. Such an approach creates more cost effective projects.
- Proper risk allocation leads to good working relationships between the parties, which, in turn, reduce the disputes, mistrust and misaligned incentives.

The investigations like this have caused the public and private owners change their contractual risk allocation mentalities in developed countries since 1980s.

It seems that the above principles are not applicable in Design-Build contract system due to the single point responsibility of the contractor. However, "owners who attempt to avoid responsibility for all project risk are likely to experience not only higher project costs but also conflicts and disputes, eliminating one of the major advantages of the design-build delivery approach" [63]. For this reason, the owners generally perform the following attempts in case of establishing a Design-Build contract [54]:

- Identifying the project risks
- Determining the risks that will be retained by owner
- Determining the risks that will be transferred to design-builder and the adjustment of pricing for this transfer
- Determining the risks that will be transferred to subcontractors and other third parties
- Developing the insurance program to handle project risks

It is clear that allocating a risk to a party who is not capable of managing it and who is not desirous is meaningless. For this reason, contractual clauses concerned with risk allocation matter should be prepared in detailed and logical terms, and all the responsible parties should examine them properly before signing on the contract documents. Necessary objections to these clauses should be made during this pre-sanctioning period.

3.5.11 Success factors of Design-Build contract system

Researches conducted on the attributes of successful construction projects so far have also provided valuable information about the success and failure factors of Design-Build construction projects. The following list is one of the findings of these researches. The list simply introduces the attributes that any Design-Build project should have and should not have in addition to the other classic properties of these kind of project contract systems [64]. Besides, the below items can be helpful in the risk identification stage of any Design-Build project.

- *Success Factors:*
  - Excellent ability of owner to make decisions
  - Adequate scope definition
  - Excellent team communications
  - Qualified contractor pool
  - High ability to restrain the contractor pool through pre-qualification and short-listing

- *Failure Factors:*
  - Contractors engaged late in the design process
  - Limited or no prior team experience
  - Onerous contract clauses
  - An owner lacking ability to make decisions
  - No pre-qualification of bidders

The shape of the standard form of contract is not the only criteria for the successful Design-Build project completion in public construction sector. Songer and Molenaar [65, 66] have made investigations to identify the appropriate project characteristics for a successful public-sector Design-Build project and have reached the following results:

- The definition and understanding of project scope is the most important element
- The critical five criteria are well-defined scope, shared understanding of scope, owner's construction sophistication, adequate owner staffing and established budget.
- The success criteria from the point of view of public owners are: staying on budget, conforming to user's expectations and staying on schedule.

Another research carried out by Chan, Ho and Tam [67] on this subject provided the results summarized below:

- Project team commitment, client's competencies and contractor's competencies are the items that bring success in Design-Build projects.
- Contractor's competencies also make contributions to the project time performance.
- The team members should be aware of that time and cost performance as well as the quality of design and workmanship constitutes the critical key elements of overall success of design-build projects.

3.5.12 Design-Build contract system in Turkey

Design-Build contract system has been utilized by public agencies of Turkey in restricted number of projects since 1980s. For instance, İzmir-Aydın Motorway Project of General Directorate of State Highways (KGM), Karkamiş Dam Project of General Directorate of State Water Works (DSİ), İstanbul Mass Housing Project of Emlak Bank Building and Estate Group, and Eight-yearly Primary School projects of the Ministry of National Education (MEB) are some of the public projects completed under Design-Build system in Turkey [68-70]. However, Design-Build system has never been formally included as an accepted contract system within the State Contract Law no. 2886 of General Directorate of Public Works. The institutions that have restrictedly executed this system are already those that are not legally dependent on this law. Fortunately, Design-Build will be the general method of public construction projects as the new form of the state contract law (The Public Contract Law - No. 4734) that is revised according to the European norms will start to have been used by the year 2003.

Design-Build is not a new concept for the private sector of Turkey. For instance, prefabricated industrial plants frequently have been constructed based on Design - Build system, particularly in developed regions of the country. Obviously, the usage area of this system will definitely expand in also private sector construction works as the utilization of the system increases in public construction works. This is due to the fact that the biggest employer in the construction sector of Turkey is the state institutions and this fact will also provoke the application of the Design-Build contract system in the private construction sector.

CHAPTER 4

CASE STUDY I

4.1 Introduction

The purpose of this case study is to verify the necessity of applying risk analysis and management techniques in Design-Build construction projects. The content of the study is essentially hypothetical and the payment methodology chosen is fixed-price. This preference is due to the fact that risk management actions turn to be vital activities for catching success in more risky environment of a fixed-price Design-Build project. Through the case study, besides the risk analysis and management practices, the specific characteristics of Design-Build contract system will be available to be observed because the base scenario of the study also contains the preparation, evaluation and awarding stages of the proposed project from both owner's and contractor's (design-builder) point of views. However, the risk management applications would be conducted from the side of a bidding contractor. The project risks will be identified and examined based on the clauses of the FIDIC's (International Federation of Consulting Engineers) Design-Build standard form of contract, for the reason FIDIC' s standard form of contracts are widely used in Europe and Turkey aims to become a member of European Union in near future [71]. Moreover, the discussion will be focused around the inherent risk allocation issues associated with the main participants of the contract, who are design-builder and owner.

The analysis of the identified risks will be carried out mainly by Monte Carlo Simulation. This technique is appropriate to build cost, schedule and cash flow risk models with the help of the computer programs and to evaluate the risks of the current hypothetic project along the preparation period towards the tender. The programs that would be used for planning, modeling and simulating purposes are respectively, MS Project, MS Excel and Crystal Ball. Crystal Ball is an Excel add-in that is developed for risk analysis on the Excel's spreadsheet environment [73].

The followings are the summary of the case study's objectives and scope as discussed above:

- To apply risk analysis and risk management techniques on management of a construction project contracted under Design-Build contract system and verify their necessity.
- To distinguish the basic characteristics of Design-Build system throughout the tender preparation period.
- To explore the extra risks of fixed-price Design-Build contract system.
- To discuss the risk allocation issues of FIDIC' s design-build standard form of contract, which is used as a base contract model for this case study.
- To observe the power of Monte Carlo simulation during the analysis of the risks.
- To observe the modeling and simulating capacities of the utilized computer programs.

4.2 General Information

4.2.1 Scenario

Turkey, which is a developing European country, aims to solve the economic problems associated with the country's economic structure in order to overcome the recent national financial crisis and so to be ready for getting the entrance right to the European Union. The world's leading money supplier organization, IMF (International Money Fund) seems to be supporting the Turkish government in achieving these structural reforms through a strict program directly organized by them. The proposed reforms by the organization mainly include the privatization of the state institutions such as state banks, state village works, state water works and state telecommunication facilities. For this reason, Turkish government follows the IMF' s directives under the governance of this international organization's representatives.

The leading item of the IMF' s economic program is to make the necessary modifications on the banking sector of the country and prepare the state banks to the privatization process. In order to achieve this, all the state and private banks have been started to be controlled and governed by a central managing group (BDDK, the senior association for regulation and inspection of banking sector) that is appointed by the recent government. The first activities of BDDK have been closing the private banks that have been governed unsuccessfully so far by their owners. Next, BDDK started the 'structural reform period' concerning the biggest state banks that are Ziraat Bank, Halkbank and Emlakbank. Emlakbank has been already liquidated according to this reform package by the end of year 2001 and its duties and personnel have been transferred to Ziraat Bank and Halkbank by transfer protocols. Therefore, two state banks have remained to be prepared for privatization by the end of year 2002, according to the IMF' s program.

The scenario of this case study has been shaped around the real issues experienced in Turkey, which are introduced in the above paragraphs. It is assumed that the structural reform period, which is planned to be achieved by the end of 2002, has been succeeded in time and Ziraat Bank has become ready to be sold by the beginning of 2003. The whole scenario that is produced based on this assumption is given below:

Ziraat Bank, which has been the biggest state bank of Turkey serving inside all over the country and in a number of foreign countries since more than 100 years, has been put on sale by the Turkish government according to the economic reform program of IMF. An international bank, Deutsche Bank, and its national partners have won the competition and succeeded to buy Ziraat Bank, however, with possessing the dominant portion of the Bank and so having also the governing power of the Bank.

After getting the possession of the Bank's real estates, financial resources and the governing liability, the senior board of Deutsche Bank and its Turkish partners has decided to start an architectural alteration and repairing program concerning the Bank's all office buildings all over the country. The purpose of this alteration program is to enter the banking sector of the country with a new and modern image and to recover the bad reputation of Ziraat Bank's old offices.

The managers of the Bank negotiate with an architectural/engineering consultancy firm for making and directing the pre-tender, tender, awarding and contract management operations of this image alteration project. The consultancy firm comprehends the owner's needs and requests during meetings and negotiations, and offers the Bank's managers to make seven separate tenders for seven separate regions of the country due to the economic and regional reasons. Except for this, the firm offers fixed-price Design-Build contract system for this construction project. At the end of a few meetings, the senior management of the Bank accepts all of the *advices of the consultant firm.*

The new owners of the Bank consider great importance for the eighteen central and fifty-two dependent offices existing in the southeastern region of the country due to the sensitive socio-economic features of the region. For this reason, the consultant firm prepares a detailed request program of the project and then invites three design-build contractor firms of the region to the competition. Afterwards, these design-build firms receive the request program from the consultant firm and attend to the tender after preparing their preliminary designs, schedule plans, estimated tender prices and risk analysis results.

4.2.2 Participants

The participants of the case study will be called with their general names throughout the case study. In other words, general names will be used instead of the special names in the next sections. The general names of the parties included in the study are listed below:

- Owner: Deutsche Bank and its national partners (Senior Managing Board)
- Owner's Representative: Architectural/Engineering Consultant
- Design-Builder A, B, C: Three contractors invited to the tender
- Designer A: Architect/Engineering Design team of Design-Builder A
- Construction Planner A: Planning team of Design-Builder A

4.2.3 Methodology

The way that will be followed along the study naturally has a methodological characteristic. The methodology will be a stepwise phenomenon as briefly mentioned in the introduction section. In order to make it clearer, the outline of the study's steps is presented below:

- *Step1* Preparation of the request and tender program of the Owner by the Owner's Representative
- *Step 2* Delivery of the request and tender programs to the invited Design-Builders
- *Step 3* Preparation of the Design-Builders to the tender
  - from the viewpoint of Design-Builder A:
    - Preliminary Design
    - Cost Estimating
    - Schedule Planning
    - Risk Analysis and Management
- *Step 4* Competitive tender and evaluation of the Design-Builders' proposals by the Owner's Representative

4.3 Step 1 – Owner's Preparation for the Tender

The requests and needs of the owner have to be investigated and documented by the Owner's Representative in order to inform the Design-Builders about the project. For this reason, the Owner's Representative performs the following activities:

- Arrange meetings with the Owner
- Visit the south eastern region of the country and examine the conditions of present offices and buildings of the Bank

- Identify the probable risks which might be faced

The Owner's Representative plans to carry out above activities and reaches to the tender program in three stages:

- Stage 1 – Queries to the Owner
- Stage 2 – Investigations in the region
- Stage 3 – Preparation of the tender program

4.3.1 Stage 1 – Queries to the owner

The Owner's Representative prepares the query list and takes answers to these questions during the meetings with the Owner. The aim here is to determine the main needs and requests of the Owner.

The query list consists of the following items:

- Which offices on the region are going to be reconstructed?
- Which offices have priority in the project program?
- In what percentage are the offices and buildings going to be redecorated? For instance, are all the materials and architectural features going to be changed or some of the parts going to be protected?
- Are there any limitations concerning the project duration and budget?
- What are the whole addresses, scales and personnel densities of the offices that will be reconstructed?
- Is the new image of the Bank going to have similarities with the other offices of the Bank in abroad or other offices that will be redecorated in other regions of the country?

- Is there any limitations concerning the type of materials to be used?
- Are there any offices or buildings that will be closed up and sold?

4.3.2 Stage 2 – Investigations in the region

After the determination of the Owner's needs and requests, it is the time to investigate the region. This process is necessary in exploring the probable risks that will be faced during the project and predicting the feasibility of the construction according to the requests of the Owner.

The subject matters of the investigation are listed as follows:

- The accuracy of the offices' locations and addresses given by the Owner
- The exact distances between the office buildings
- The transportation facilities between the office buildings
- The number of stories of the office buildings and their landing/usage areas
- The weather conditions in the region during a year
- The architectural features of the other Banks' offices in the region
- The manufacturing capacity of the construction industry in the region
- The existence of material suppliers and labor force
- The other specific risks related to the regional characteristics
- The appropriateness of the offices that will be redecorated or sold

Furthermore, the Owner's Representative prepares the technical map of the region that consists of the locations of the offices and buildings of the Bank, roads between these locations, the locations of the material suppliers and industrial organizations and etc. This map will be helpful for the Design-Builders in preparing their risk analysis models and tender proposals.

4.3.3 Stage 3 – Preparation of the tender program

The next stage performed by the Owner's Representative is the preparation of the tender program under the light of the data and information gathered in the previous two stages. In other words, tender program is mainly composed of the answers that have been taken so far. This program can also be called as the 'Owner's request report' or 'request for proposals'.

The important points of the resultant tender program is given below:

- All the office buildings belonging to the Bank in the eight cities of the southeastern part of the Country will be redecorated through the image alteration project. (Table 4.1)
- The central office buildings existing in the city centers have to be given priority in the construction schedule. The names of these offices and their locations are given in Table 4.1.
- All the existing materials must be removed and a completely new image has to be created. However, the image must be unique for all offices. The Design-Builders are free to propose their own designs and there is no obligation for the design features to resemble the offices of the Bank in abroad or other offices in the region.
- The Owner desires all the offices to be completed as early as possible, especially the central offices earlier than others. There is no limitation for the cost due to the lack of material and design restrictions. Nevertheless, the shorter project schedules and less cost proposals will be the two important criteria in the evaluation of the bids.
- The names, locations and personnel numbers of the offices in the region are

given in Table 4.1.

- All offices will have new type automatic money machines (ATM). These machines are going to be submitted to the Design-Builders in parties as the project progresses.
- All lodging and local buildings will be closed and sold. For this reason, these buildings are out of the scope of the project.
- There is no problem regarding the transporting availabilities except for the probable obstacles during the winter season particularly in the parts mentioned in Table 4.1.
- The net floor areas of the office buildings are given in Table 4.1.
- Unskilled labor force is cheap and abundant in the region but skilled labor force is rare.
- Weather is very hot in almost all the region in summer, i.e. it is between 35 °C and 45 °C. However, some problems may be encountered in some cities mentioned in Table 4.1 in winter season.
- The manufacturing industry is sufficiently developed and organized in Gaziantep, Şanlıurfa and Diyarbakır. However, special construction materials and applications might not exist.
- There exist regional representatives of the main material producers of the construction sector of the Country particularly in Diyarbakır, Şanlıurfa and Gaziantep.

Table 4.1 General information about the office buildings included in the tender program

Name of the city	Name of the office	Personnal No.	ATM No.	Weather in winter	Weather in summer	Net floor area (m2)
Diyarbakır city center	Diyarbakır/central	45	yes(1)	no problem	no problem	1000
	Bağlar/central	8	yes(1)	no problem	no problem	300
	Ofis/central	8	yes(1)	no problem	no problem	400
	Yenişehir/central	8	yes(1)	no problem	no problem	200
	University/central	6	yes(1)	no problem	no problem	200
Diyarbakır towns	Bismil	8	yes(1)	no problem	no problem	600
	Çermik	6	yes(1)	no problem	no problem	400
	Çınar	6	yes(1)	no problem	no problem	300
	Çüngüş	6	yes(1)	problemetic	no problem	300
	Dicle	6	yes(1)	problemetic	no problem	300
	Eğil	4	yes(1)	no problem	no problem	200
	Ergani	8	yes(1)	no problem	no problem	300
	Hani	6	yes(1)	problemetic	no problem	300
	Hazro	4	yes(1)	problemetic	no problem	300
	Kulp	4	yes(1)	problemetic	no problem	200
	Lice	4	yes(1)	problemetic	no problem	200
	Silvan	6	yes(1)	no problem	no problem	400
Şanlıurfa city center	Şanlıurfa/central	45	yes(1)	no problem	no problem	1000
	Haşimiye/central	8	yes(1)	no problem	no problem	500

Table 4.1 (cont'd)

Name of the city	Name of the office	Personnal No.	ATM No.	Weather in winter	Weather in summer	Net floor area (m2)
Şanlıurfa towns	Akçakale	4	yes(1)	no problem	no problem	200
	Birecik	8	yes(1)	no problem	no problem	300
	Bozova	8	yes(1)	no problem	no problem	300
	Ceylanpınar	8	yes(1)	no problem	no problem	400
	Halfeti	6	yes(1)	no problem	no problem	400
	Harran	4	yes(1)	no problem	no problem	300
	Hilvan	4	yes(1)	no problem	no problem	200
	Siverek	8	yes(1)	no problem	no problem	400
	Suruç	8	yes(1)	no problem	no problem	300
	Viranşehir	8	yes(1)	no problem	no problem	300
Gaziantep city center	Gaziantep/central	45	yes(1)	no problem	no problem	1000
	Akyol/central	8	yes(1)	no problem	no problem	600
	Karşıyaka/central	8	yes(1)	no problem	no problem	600
	Şırahanı/central	8	yes(1)	no problem	no problem	500
	Suburcu/central	8	yes(1)	no problem	no problem	300
	University/central	6	yes(1)	no problem	no problem	200
Gaziantep towns	Araban	6	yes(1)	no problem	no problem	200
	Islahiye	8	yes(1)	no problem	no problem	300
	Karkamış	8	yes(1)	no problem	no problem	300
	Nizip	8	yes(1)	no problem	no problem	500
	Nurdağı	4	yes(1)	no problem	no problem	200
	Oğuzeli	6	yes(1)	no problem	no problem	300
	Yavuzeli	6	yes(1)	no problem	no problem	300

Table 4.1 (cont'd)

Name of the city	Name of the office	Personnal No.	ATM No.	Weather in winter	Weather in summer	Net floor area (m2)
Batman/city center	Batman/central	35	yes(1)	no problem	no problem	1000
Batman towns	Beşiri	6	yes(1)	no problem	no problem	400
	Gercüş	4	yes(1)	problemetic	no problem	200
	Kozluk	8	yes(1)	problemetic	no problem	600
	Sason	4	yes(1)	problemetic	no problem	500
Siirt/city center	Siirt/central	35	yes(1)	no problem	no problem	1000
Siirt towns	Baykan	6	yes(1)	problemetic	no problem	200
	Eruh	4	yes(1)	problemetic	no problem	400
	Kurtalan	6	yes(1)	no problem	no problem	400
	Pervari	4	yes(1)	problemetic	no problem	400
	Şirvan	4	yes(1)	problemetic	no problem	300
Kilis/city center	Kilis/central	20	yes(1)	no problem	no problem	600
Kilis/towns	Musabeyli	8	yes(1)	no problem	no problem	300
Şırnak/city center	Şırnak/central	20	yes(1)	problemetic	no problem	400
Şırnak towns	Beytüşşebap	4	yes(1)	problemetic	no problem	300
	Cizre	8	yes(1)	problemetic	no problem	500
	İdil	6	yes(1)	problemetic	no problem	200
	Silopi	8	yes(1)	no problem	no problem	600
	Uludere	4	yes(1)	problemetic	no problem	300

Table 4.1 (cont'd)

Name of the city	Name of the office	Personnal No.	ATM No.	Weather in winter	Weather in summer	Net floor area (m2)
Mardin/city center	Mardin/city center	35	yes(1)	no problem	no problem	600
Mardin towns	Derik	6	yes(1)	problemetic	no problem	300
	Kızıltepe	8	yes(1)	no problem	no problem	500
	Midyat	8	yes(1)	no problem	no problem	400
	Midyatkesimi	6	yes(1)	no problem	no problem	300
	Nusaybin	8	yes(1)	no problem	no problem	400
	Ömerli	6	yes(1)	no problem	no problem	600
	Savur	4	yes(1)	no problem	no problem	300
	Yeşilli	4	yes(1)	no problem	no problem	300

4.4 Step 2 – Delivery of the Tender Program

This activity consists of determining the design-build firms that will be invited to the tender and delivering the tender program prepared in the preceding step. Moreover, a copy of the FIDIC' s design-build contract form is also submitted to the contractor firms so that they can analyze the contract's content and comprehends the participants' liabilities and risks. Furthermore, the clauses of the contract and its appendixes clarify the clues about many issues that would be necessary in preparing risk analysis models and risk response strategies. The contractors also become available to find out the disputable parts of the contract and solve the problems in advance by this way.

The Design-Builders are informed about the date, location and rules related to the tender in this step. All the questions that might come from the contractors about the project are tried to be answered at this step by the Owner's Representative. This also helps the Owner's Representative identify the other project risks that may not have been recognized in the tender program preparation stage and once more, Owner's Representative acts as an information bridge between the Owner and Design-Builders.

The Owner's Representative sends invitation letters to the selected Design-Builders after completing all the preparation works concerning the tender and starts to wait for Design-Builders come and take other documents and further information about the project and tender. The invitation letter is mainly composed of the exact date, time and location of the competitive tender, the name of the project, the basic rules related to the evaluation and awarding, and necessary official documents for participating to the tender. Moreover, it is mentioned in the letter that the other documents such as 'Owner's Tender Program' and 'FIDIC' s Design-build Contract Form' are ready and can be submitted to the Design-Builder during the tender preparation period.

The items below are the summarization of the items included in the invitation letter:

- The date of the letter: 'February 10^{th}, 2003'
- The name of the project: 'Alteration project of Deutsche Bank's office buildings in the South Eastern Region'
- The contract method: 'Fixed-price Design-Build contract system'
- The contract form: 'FIDIC' s design-build Form of Contract'
- The date of tender: 'April 15^{th}-17^{th}, 2003'
- The time of tender: '10.00 ^{am}-14.00^{pm}'
- The location of tender: 'General Directorate of Deutsche Bank, Ankara'
- The evaluation criterions: 'Duration, cost, architectural design'
- The awarding method: 'Weighted criteria'

4.5 Step 3 – Design-Builders' Preparation for the Tender

As previously emphasized, this step will be conducted from Design-Builder A's point of view. It is assumed that Design-Builder A obtained all the necessary documents from the Owner's Representative and now prepares his tender documents.

Design-Builder A, first of all, organizes his design and construction teams (Designer A, Construction Planner A) and determines their duties and responsibilities. Due to the previous experience, he is conscious about the necessity of collaborative teamwork for taking successful results during the tender and project application. The responsibilities of the teams are as follows:

-Designer A-

- To prepare the typical architectural design
- To prepare the typical ATM cabin design

- To prepare the typical electrical (e.g. lighting system, generators and computer cable system) and mechanical (e.g. waste water, drinking water and HVAC systems) designs
- To work in coordination with the Construction Planner A during the project planning

-Construction Planner A-

- To investigate the regional conditions and other Bank offices in the Region
- To arrange agreements with subcontractors
- To prepare the schedule
- To estimate the fixed-price
- To identify the project risks
- To perform risk analysis
- To examine the contract documents
- To decide risk response strategies
- To prepare the tender presentation files in coordination with Designer A

Design-Builder A's team has to complete the above operations within approximately two months as it has been mentioned in the tender invitation letter. For this reason, the team should quickly start to work. The following sub-sections describe the undertaken tasks and results produced by Designer A and Construction Planner A, respectively.

4.5.1 Designer A's preparation for the tender

The design and construction teams work together in a Design-Build project. This fact creates an advantageous environment for the production of innovative solutions to the project problems. Furthermore, this advantage is valid during both pre-tender and post-tender project stages and perhaps the most important profit of design-build lays here. Next, the planning and construction site activities can start after some progress in design and this shortens both the project preparation and execution durations.

In this context, Designer A works collaboratively with the Construction Planner A during the preparation for the tender. However, the first activities have to be performed by the designer team because the construction planning team can realize limited things without having sufficient data such as preliminary design and material list. For this reason, Designer A starts to prepare the preliminary design projects while Construction Planner A commences to search the region and possible construction risks.

The design team (Designer A) is comprised of architects, civil engineers, mechanical engineers and electrical engineers. The whole staff is aware of the limited tender preparation period, which is approximately two months. They should provide enough volume of data to the construction planning team (Construction Planner A) as early as possible in order for the planner team finishes all the tender preparation processes in two months.

The architects, together with the other members of the team, choose an office building as a typical model and draw all the preliminary projects based on this model. The model building has three stairs: basement floor, first floor and half storey. The first task undertaken by the team is taking measurements of the model building in place. Then, the architects decide the construction materials together with the engineers of the team. Afterwards, the architectural, mechanical and electrical 2-D and 3-D projects are produced, respectively. Since the designing activities are out of the scope of this study, only text explanation of the final model design has been added to the Appendix A (Design Model Explanation). This information is enough for comprehending the technical content included in the next sections.

4.5.2 Construction Planner A's preparation for the tender

The team of Construction Planner A is composed of construction managers (civil engineers), mechanical engineers and electrical engineers. They investigate the region and explore the construction risks while the design team (Designer A) has been preparing the model design. As soon as enough level of progress is achieved in designing of the model, Designer A delivers the gathered data to the Construction Planner A without waiting the completion of the whole design. In other words, both teams benefit from the advantages of the Design-Build system even before the execution of the whole project.

4.5.2.1 Identification and classification of project risks

Construction Planner A identifies the following risks after examining the region, the FIDIC' s design-build contract and the submitted data of the model design.

- Defective design
- Design changes
- Delays in design
- Subcontractors' default
- Fluctuation in labor productivity
- Delay in resolving disputes
- Owner delays (unable to get approvals, lack of payment, delayed progress payments)
- Difficulties/delays in availability of materials, equipment and labor
- Inadequate quality of work and need for correction
- Changes in quantity/scope of work
- Inflation

- Weather conditions
- Accidents
- Social events

Construction Planner A applies the second step of risk management, which is risk classification, after identifying the project risks (Figure 2.3). The results of this step are given in Table 4.2. The above risks are qualified according to their types, impacts and consequences in this table. The ‘consequence’ column of the table consists of information about whether the corresponding risk affects directly the total cost or the total duration of the project. In fact, all risks affecting the total duration also affect the total cost indirectly because time means money. However, only direct effects of the risks are taken into account when analyzing them. Naturally, response strategies are also decided accordingly. Nevertheless, as it can be seen in Table 4.2, some risks like ‘owner delays’ are directly effective on both cost and duration. Such classifications are important while setting up schedule and cost risk models of the project. For instance, only the risks of which the ‘consequence’ is ‘duration’ are used in performing schedule risk model.

Table 4.2 Risk classification table

Risk No.	Risk Description	Type	Impact	Consequence
1	Defective design	Pure	Project	Duration, Cost
2	Design changes	Pure	Project	Duration
3	Delay in design	Pure	Project	Duration
4	Subcontractors' default	Pure	Project	Duration
5	Fluctuation in labor productivity	Speculative	Project	Duration
6	Delay in resolving disputes	Pure	Project	Duration
7	Owner delays (unable to get approvals, lack of payment, delayed progress payments)	Pure	Company	Duration, Cost
8	Difficulties/delays in availability of materials, equipment and labor	Pure	Project	Duration
9	Inadequate quality of work and need for correction	Pure	Project	Duration, Cost
10	Changes in quantity/scope of work	Speculative	Project	Duration, Cost
11	Inflation	Pure	Environmental	Cost
12	Weather conditions	Pure	Project	Duration
13	Accidents	Pure	Project	Duration, Cost
14	Social events	Pure	Project	Duration, Cost

Construction Planner A examines the clauses of FIDIC' s design-build contract form in order to verify which party carries the responsibility of the identified risks. This is another important issue when analyzing the risks because Construction Planner A carries out the risk management and analysis processes on behalf of the Design-Builder A. In other words, there is no need for the Construction Planner A to take the risks into account up to a full extent, which are under the full responsibility of the Owner contractually.

After examining the FIDIC' s contract documents, Construction Planner A concludes that the 'social events' risk is completely under the responsibility of the Owner. (Appendix B - Risks and Contract Clauses) For this reason, there is no need to take this risk into account in risk analysis. Other risks are allocated between the Owner and Design-Builder in varying portions. The risk allocation subject is discussed in

Appendix B. This section consists of necessary information to determine the influencing power of risks on project duration and cost. Since, the uncertainty range of the project values in a risk analysis model varies according to the relevant party's contractual risk load, it is impossible to analyze the risks without examining the contract documents. Otherwise, the results of the analysis would not be realistic. The results of 'Risks and Contract Clauses' section are summarized in Table 4.3.

Table 4.3 Risk allocation table

Risk No.	Risk Description	Consequence	Allocation
1	Defective design	Duration, Cost	Design-Builder
2	Design changes	Duration	Shared
3	Delay in design	Duration	Design-Builder
4	Subcontractors' default	Duration	Design-Builder
5	Fluctuation in labor productivity	Duration	Design-Builder
6	Delay in resolving disputes	Duration	Shared
7	Owner delays (unable to get approvals, lack of payment, delayed progress payments)	Duration, Cost	Shared
8	Difficulties/delays in availability of materials, equipment and labor	Duration	Design-Builder
9	Inadequate quality of work and need for correction	Duration, Cost	Design-Builder
10	Changes in quantity/scope of work	Duration, Cost	Shared
11	Inflation	Cost	Design-Builder
12	Weather conditions	Duration	Design-Builder
13	Accidents	Duration, Cost	Design-Builder
14	Social events	Duration, Cost	Owner

4.5.2.2 Schedule risk analysis

Construction Planner A analyses the identified project risks in three steps:

- Schedule risk analysis

- Cost risk analysis
- Cash flow risk analysis

Schedule risk analysis, which is the first step of risk analysis, is performed in two groups. The first group that is worked on is the 18 central offices and the second group is the 52 town offices. Construction Planner A separates the offices into two groups like this, because the Owner emphasizes the priority and importance of the central offices in the tender program. For this reason, it turns to be an advantage for the Design-Builder in the competitive tender to locate the central offices at the beginning of the project schedule plan.

Moreover, schedule risk analysis is performed in two dimensions within each group. The first dimension is the analysis of each office with Monte Carlo simulation inside itself. In contrast, the second dimension is the connected analysis of all the offices with the Critical Path Method, Gantt chart method and resource allocation capability of MS Project by means of the results of the first dimension. In other words, the first dimension is a stochastic analysis, whereas the second dimension is mainly deterministic.

The important assumptions of Construction Planner A's schedule risk analysis are as follows:

- Designer A organizes two independent design groups; each constitutes architects and engineers.
- Construction Planner A organizes four independent construction groups; each constitutes engineers and foremen.
- The duration of designing an office having 500 m^2 floor area is 10 days. It is assumed that design duration is directly proportional to the floor area. The design durations of the other offices that have 200, 300, 400, 600 and 1000 m^2 floor area are calculated based on these assumptions.

- It is assumed that construction can start as soon as the design projects are examined and approved by the Owner's Representative. However, it is assumed that the approval period of the Owner's Representative is 5 days after the design projects are delivered to him.

Under the light of the above assumptions, Construction Planner A performs time schedule analysis of the offices through the following stages.

1-) Determine network elements & values:

Any schedule risk planning starts with determining the network elements & values, which are construction activities, their successors and predecessors, and activities' minimum, maximum and most likely durations. This process mainly depends on the Planner's past experience and historical records related to previous projects. Nevertheless, the accuracy of the values and the network logic is extremely important for getting realistic results from risk analysis.

Table C1, C2, C3, C4, C5 and C6 consist of the network information of the offices possessing 200, 300, 400, 500, 600 and 1000 m^2 net floor area. The activities and predecessors are almost the same for all the offices but activity durations and maximum-minimum duration ranges change with respect to the floor area.

2-) Build schedule risk analysis network model:

Network model is set up by means of mathematical formulas providing the network relationship between the activities. MS Excel is an excellent table processor for such a purpose. The Excel worksheets prepared for the offices possessing 200, 300, 400, 500, 600 and 1000 m^2 net floor area are given in Table C1, C2, C3, C4, C5 and C6, respectively. The cells of these worksheets are also connected by mathematical formulas to the simulation background sheet that is developed on a separate Excel page (Ref. 4^{th} stage).

3-) Build activity-risk factor matrix:

There are 12 main project risks in total and each risk affect each activity's duration differently. This variety is represented in percentages in Table 4.4, which is called the table of activity-risk factor matrix. It makes the analysis more realistic to take these percentages into account in the model. The risk percentages or risk factors depend on judgment and experience of the Planner.

All of the items produced up to here are utilized in Monte Carlo Simulation. In order to enable Monte Carlo Simulation to calculate the activity durations stochastically, the following equation (2.1) is developed after some reformation on Dawood' s [44] equation (2.2). These equations are also emphasized in Chapter 2.

$$\text{Duration of activity} = \text{MAX}\,[(\text{Min. Time} + \text{Risk Factor Affect}), (\text{Max. Time} - \text{Risk Factor Effect})] \quad (2.1)$$

$$\begin{aligned}\text{Duration of activity} = \text{MAX}\,[&[\text{Min.Time} + (\text{Max.Time} - \text{Min.Time}) \text{ X } [(RF_1 \text{ X } Random_1) + (RF_2 \text{ X } Random_2) + \ldots\ldots\ldots + (RF_n \text{ X } Random_n)]],\\ &[\text{Max.Time} - (\text{Max.Time} - \text{Min.Time}) \text{ X } [(RF_1 \text{ X } Random_1) + (RF_2 \text{ X } Random_2) + \ldots\ldots\ldots + (RF_n \text{ X } Random_n)]]] \end{aligned} \quad (2.1)$$

Where;

Min.Time: The minimum duration that an activity can be completed.

Max.Time: The maximum duration that an activity can be completed.

RF_n : The percent effect of n^{th} risk factor on an activity (taken from activity-risk factor matrix)

$Random_n$: is a random number, between 0 and 1, generated during Monte Carlo Simulation to represent the n^{th} risk factor's probability distribution.

$$\text{Duration of activity} = \text{Min.Time} + (\text{Max.Time} - \text{Min.Time}) \text{ X } [(RF_1 \text{ X } Random_1) + (RF_2 X Random_2) + \ldots\ldots\ldots + (RF_n X Random_n)] \quad (2.2)$$

Table 4.4 Activity-risk factor matrix

Risk No.		1	2	3	4	5	6	7	8	9	10	11	12	
Activity Number	Activity Name	Defective design	Design changes	Delay in design	Subcontractors' defaul	Fluctuation in labor productivity	Delay in resolving disputes	Owner delays	Difficulties/delays in availability of materials, equipment and labor	Inadequate quality of work and need for correction	Changes in quantity/scope of work	Weather conditions	Accidents	Total
1	Start													
2	Site delivery			0,2				0,8						1,0
3	Procure construction materials, equipment and furniture								0,5		0,2	0,2	0,1	1,0
4	Remove existing materials					0,7			0,3					1,0
5	Detail measurement; by aluminum subcontractor		0,2	0,3	0,4						0,1			1,0
6	Detail measurement; by glazier subcontractor		0,2	0,3	0,4						0,1			1,0
7	Detail measurement; by ATM cabin subcontractor		0,2	0,3	0,4						0,1			1,0
8	Detail measurement; by advertisement panel subcontractor		0,2	0,3	0,4						0,1			1,0
9	Detail measurement; by safe room subcontractor		0,2	0,3	0,4						0,1			1,0
10	Install electrical and automation fitting	0,2	0,2	0,1					0,1	0,2	0,2			1,0
11	Install HVAC, sanitary and mechanical fitting	0,2	0,2	0,1					0,1	0,2	0,2			1,0
12	Install suspended ceiling	0,2	0,2	0,1		0,1			0,1	0,2	0,1			1,0
13	Cover mechanical and electrical units					0,3			0,1	0,3	0,3			1,0
14	Level slab sub-layer (all the floors)					0,6			0,1	0,3				1,0
15	Cover slab (all the floors)					0,6			0,1	0,3				1,0
16	Paint interior walls and columns					0,6			0,1	0,3				1,0
17	Paint base floor ceiling					0,6			0,1	0,3				1,0
18	Finish WC and kitchen works	0,1	0,1	0,1		0,4			0,1	0,2				1,0
19	Install aluminum joineries	0,1			0,2	0,1	0,1	0,1	0,2	0,2				1,0
20	Install inner and outer joinery glasses	0,1			0,2	0,1	0,1	0,1	0,2	0,2				1,0
21	Install security alarm system	0,1			0,2	0,1	0,1	0,1	0,1	0,3				1,0
22	Construct ATM cabin and install money machine	0,1	0,1		0,1	0,2	0,1	0,1	0,1	0,2				1,0
23	Construct safe room and install safe box	0,1	0,1		0,1	0,2	0,1	0,1	0,1	0,2				1,0
24	Finish exterior works					0,4			0,3	0,3				1,0
25	Install advertisement panel	0,2			0,3	0,2		0,1	0,1	0,1				1,0
26	Install furniture							0,1	0,4	0,2	0,3			1,0
27	Finish interior works									0,8	0,2			1,0
28	Install communication and automation systems					0,2		0,2	0,3	0,3				1,0
29	Check all the works and test all the systems	0,2			0,2			0,2		0,4				1,0
30	Finish													

The reason of the revision made on the original formula (2.2) is to create pessimism on the simulated activity durations. In other words, it enables the risk analysis program to select the maximum simulated value for the activity and this trend leads to pessimism. This approach can also be considered as a risk mitigation strategy.

4-) Build simulation background:

Activity-risk factor matrix (Table 4.4) is connected to the worksheet model by means of Equation 2.1 and the statistical distributions that represent the occurrence frequencies of the risks. Crystal Ball, which is an Excel add-in program, is capable of attaching various types of probability distributions of this kind. The distributions representing the 12 project risks are shown in Table C7. Crystal Ball selects random numbers between 0 and 1 to be used in Equation 2.1 with respect to the shape, type and statistical characteristics of these probability distributions. The Planner benefits from his experience and engineering judgment while determining the risks' probability distributions.

5-) Determine correlation coefficients:

Correlation coefficients should be introduced into the model prior to Monte Carlo Simulation if correlation exists between the risks. Crystal Ball has the capability of setting correlation or adjusting the predetermined coefficients. Table C8 shows the correlation coefficient values assessed by Crystal Ball based on the probability distributions given in Table C7.

6-) Enter simulation preferences:

Crystal Ball makes it easy to set or change the simulation characteristics such as iteration number, seed value and simulation type. The selected preferences for the current analysis are as follows:

- Iteration number: 5000
- Initial seed value: 400
- Simulation type: Monte Carlo Simulation

7-) Execute Monte Carlo Simulation:

Monte Carlo Simulation is used separately for each category of net floor area. The resultant risk percentiles are given in Table 4.5. Each duration for each probability percentage in this table gives the probability of completing the construction part of each office of different net floor area for the corresponding duration. For instance, the construction of an office having 600 m^2 net floor area can be completed in 49 days with 60 % of probability.

Table 4.5 Probable durations of construction in percentiles

Percentile	*Construction Duration (days)*					
	200 m2	*300 m2*	*400 m2*	*500 m2*	*600 m2*	*1000 m2*
0%	32,0	33,1	36,8	44,2	44,2	55,2
10%	33,4	34,4	38,4	46,1	46,1	57,3
20%	33,7	34,8	39,0	46,8	46,8	58,0
30%	34,0	35,1	39,4	47,3	47,3	58,6
40%	34,3	35,4	39,8	47,7	47,7	59,1
50%	34,6	35,6	40,2	48,2	48,2	59,7
60%	34,9	35,9	40,7	48,7	48,7	60,3
70%	35,2	36,3	41,2	49,3	49,3	61,0
80%	35,7	36,7	41,8	50,0	50,0	61,8
90%	36,3	37,4	42,7	51,1	51,1	63,0
100%	39,9	40,8	46,9	56,0	56,0	68,3

8-) Evaluate the simulation results:

The results are examined for the purpose of assessing the risk level to be used in deterministic planning. The risk level that the Construction Planner A utilizes is 60%. The construction durations of offices of different areas according to this risk level are given in Table C9.

9-) Assess design durations:

Design durations of the offices of different floor areas are also given in Table C9.

10-) Build schedule plan of the project:

MS Project is used for this purpose. Design/construction activities, their durations, resources, activities, predecessors, project start date, working times and other project data are input into MS Project and then the schedule plan of the two office groups (central offices and town offices) are formed connectively. The resultant schedule plans of the two office groups are given in Table C10 and C11.

4.5.2.2.1 Results of schedule risk analysis

The results of schedule risk analysis are as follows:

- If the construction team is composed of two design groups and four construction groups and if six days of the week is the working time (i.e. without any other holidays except for Sundays), the project of central offices will be completed within 292 days and the whole project will be completed within 878 days at the 60 percent risk level (Table C10 & C11).
- If only classic schedule analysis (i.e. deterministic Critical Path Method) had been conducted, the project duration of the central offices, for instance, would have been found as 253 days. This shows that the project duration calculated by even the 60 percent of risk level, which can be considered as a high-risk undertaking, is 39 days greater than the likely duration. In other words, schedule risk analysis improves the accuracy and rationality of the time predictions of the Construction Planner A, and Design-Builder A gets the ability of making more precise time estimations with the resources in hand by this way.

- Construction Planner A also becomes aware of the most probable critical activities of the construction due to the last columns of Tables C1 – C6. These columns enable the simulation to find out the activities' frequencies of falling into criticality. This means that the effects of changes on critical paths due to the changing activity durations during Monte Carlo simulation can be observed within the simulation report of Crystal Ball.
- The Equation 2.1 and the followed methodology during the conduction of schedule risk analysis lowers the negative influence of the wrong probability distribution selection and wrong correlation coefficient assignment. The risk analysis results, in turn, only become sensitive to the accuracy of the predicted maximum-minimum duration range, network logic and activity-risk factor matrix.

4.5.2.3 Cost risk analysis

The next step of the Construction Planner A's risk analysis process is the cost risk analysis. It is actually predicting the design and construction costs of each office category of different net floor area. Instead of the traditional deterministic cost estimating, i.e. summing up the most likely cost of each item, Monte Carlo simulation is used to predict the total cost stochastically.

The cost of designing and constructing of an office is composed of five cost items:

- Design cost
- Construction cost
    - Labor cost
    - Material cost
    - Subcontractor cost
    - Overhead cost

The cost of tools and light construction equipment is included in the material cost item. Besides, overhead cost consists of the indirect expenses, general expenses, transportation expenses and accommodation expenses. Labor cost item includes the fees of all technical staff, workers, foremen and accountants. Design cost is considered separately from the construction cost.

Turkish Lira is the currency unit used throughout the cost risk analysis. Furthermore, the prices of April 2003 are predicted and taken into account as the base prices. Although the contingency allowance, which is the amount of money added to the base cost for unexpected situations or risks, is provided at the cost risk analysis step; time value of money, cost escalation, profit margin and inflation are later considered at the cash flow risk analysis step. The total project cost that will be proposed by Design-Builder A in the competitive tender can only be predicted after the cash flow risk analysis step because cash inflow and outflow movements along the project schedule and the present effect of these movements (i.e. present value and net present value) will be considered at this step. Since, the payment method offered by the Owner's Representative is fixed-price, a single present value is needed for the Design-Builder A's tender price.

The risks influencing the design and construction processes create uncertainty on the cost values. Then, it becomes unrealistic to talk about certain and single cost values. Instead, the cost values can be represented with cost ranges of maximum, minimum and most likely costs, and probability distributions can be assigned to these cost ranges to represent the cost uncertainty. This is already the logic of Monte Carlo simulation method. The cost risk model prepared with this logic is shown in Table C12. The cost values in this model are the estimated values and mainly dependent on experience, judgment, market costs and previous records. Triangular distribution is used for all the cost items of the model (light gray cells) because it is easy to describe a triangular distribution with 3-point cost estimates (i.e. max., min., likely). Furthermore, Monte Carlo simulation is applied in two different forms: correlated and uncorrelated, to see the effect of the correlation assignment on the simulation results. The correlation is proposed only between labor, subcontractor and overhead cost items. Besides, 5000 iterations are conducted and the same seed value, 300, is used in each simulation case in order to make comparison between the results of correlated and uncorrelated simulations. Dark gray cells in Table C12 consist of the total simulated cost, i.e. the sum of the values simulated from the distributions of light gray cells. The results of the correlated and uncorrelated simulations are given simultaneously in the form of percentile cumulative probability values in Table C13.

4.5.2.3.1 Results of cost risk analysis

The simulation results of the cost risk model given in Table C13 shows that the chance of getting the project costs calculated by traditional deterministic method (i.e. summing up the most likely cost of each item) is very low: approximately 20% to 30%. For instance, while the most likely project cost of 500 m^2 office is predicted as 129000 million TL in Table C12, it is observed from the simulation results of 500 m^2 office in Table C13 that the possibility of completing the project at this amount is approximately 30%. This shows how it would be imprecise, inconsistent and risky to estimate the project cost without performing risk analysis.

At this point, Construction Planner A has to decide a certain risk level like in the schedule risk analysis step. This risk level will not only establish the contingency allowance amount but also take the Design-Builder A's risk attitude into account. Furthermore, the selected risk level affects the amount of fixed price tender proposal and inevitably the chance of Design-Builder A's winning the tender. However, the risk level selected should not be too high in order for not to face with unprofitable results.

It is assumed that Construction Planner A decides at 60% and 80% cost risk levels to be used at the cash flow risk analysis step. These levels can be considered as a low risk undertaking in general. However, 60% and 80% risk levels for the current simulation results means that it is still a great risk undertaking because there is a great change between the cost amount corresponding to 90% and 100% risk levels. Although this is so, it would have declined the chance of winning the tender if 100 % of risk level had been used. For this reason, 60% and 80% of risk level, which will be used at the cash flow risk analysis step, seems to be logical.

The difference between the cost values corresponding to 60% and 80% of risks in Table C13 and the cost values corresponding to the most likely total costs in Table C12 constitutes the contingency allowance amount for each office category. The contingency amount is the premium added to the most likely cost to cope with risks. However, this is not the profit margin. The profit margin will be considered at the cash flow risk analysis step. Nevertheless, this does not mean there is no relationship between the contingency amount and the profit margin. They may increase or decrease each other throughout the project.

4.5.2.4 Cash flow risk analysis

Cash flow risk analysis is the last step that is performed by the Construction Planner A along the risk analysis process. It is an important activity because the results of the schedule risk analysis and cost risk analysis are simultaneously used at this step with taking economic considerations into account such as time value of money, discount rate, inflation, profit margin, retention and net present value. For this reason, cash flow risk analysis provides a range of cost values about what should be the fixed tender price and it shows what the net present effect of the cash inflows and outflows.

In order to build the cash flow risk analysis model, some assumptions are made. They are given below:

- The design costs are separated from the construction costs for each office category of different floor area because the design tasks are carried out independently and in different times with respect to the construction tasks according to the schedule network plan that is presented in Table C10. 2,2 percent of the total simulated cost is accepted as the design cost for each office category. Such separation makes it available to locate the design and construction cash outflows on appropriate and accurate dates along the cash flow.
- As previously mentioned at the cost risk analysis step, 60% and 80% of risk levels are used for determining the design and construction costs of each office category. The 60% of risk level is mainly used for all the design costs. However, the construction costs are determined in a different way: 60% of risk level is used for the offices in Gaziantep and Şanlıurfa; 80% of risk level is used for the remaining offices. The reason of this different usage is the more risky conditions of the cities except Gaziantep and Şanlıurfa.
- The possible cost increases that may occur due to the high inflation of Turkey are reflected to the cash flow in such a way that the design and construction costs are increased within a range of 30%-45% every six month. Such an adjustment is very important for the accuracy of the fixed tender price because no price adjustment can be offered by the Design-Builder A during the project execution according to the FIDIC' s contract.
- After the adjustment of the costs according to the predicted inflation rate, 15% of profit margin is added to the design and construction costs. The profit margin is totally dependent on the Design-Builder's expectations from the project. The expected profit is sensitive to the unexpected cost increases and may decrease below the 15% if the contingency amount selected at the cost risk analysis step occurs to be insufficient.
- The cash outflows are placed at the end of the month of which the related task is finished. Afterwards, the outflows for each month are added and total monthly cash outflows are calculated.
- The real discount rate is predicted to differ between 3,5% and 6,0% in

Turkey's economic conditions. This rate range is logical because the calculations give the nominal interest rate that is recently applied by the banking sector of Turkey [45, 72]:

$$(1+n) = (1+i) * (1+r) \quad (4.1)$$

Where; n: nominal interest rate

i: monthly inflation rate (varies between 5,0%-8,0%)

r: real discount rate (3,5%-6,0%)

From the equation above (equation 4.1), n = 8,68% - 14,48%

- The payments (cash inflow) are made at the end of each month according to the contract. Nevertheless, the Owner has the right of making the payment within 56 days after the delivery of the Design-Builder's payment certificates. This creates uncertainty about where to locate the cash inflows on the cash flow. Therefore, it is assumed that the Owner makes the payment 30 days after the delivery of the documents.
- The payment amount is determined with respect to the completed construction area during that month. For instance, if the cost of 600 m^2 and 300 m^2 of net floor area is completed within a month, the 95% portion of the fixed price corresponding to the ratio 900 m^2 /total area=28200 m^2 is paid to the Design-Builder. 5% of the payment is kept by the Owner as the retention amount. However, it is repaid three months after the payment of the main portion.
- It is assumed that Design-Builder A does not get any advance payment from the Owner for designing or material purchasing spendings.

The cash flow risk analysis model prepared for finding the fixed tender price is summarized in Table C14. The only varying value in this model is the inflation rate (represented by the light gray cell), which varies between 30% and 48% every half year. Obviously, the variation in this value causes variation in the total fixed price (represented by the dark gray cell) during simulation. The results of Monte Carlo simulation performed on this model are given as percentiles in Table C16.

The net present value calculation is carried out on a separate sheet that is shown in Table C15. The difference of this model from the previous model is the cash inflows, i.e. the payments made to the Design-Builder A throughout the project. These payment values are calculated by taking the cost value corresponding to 80% probability in Table C16 as the fixed tender price, which is 18.860.721.720.000. -TL. The varying uncertain value of this model, besides the inflation rate, is the monthly nominal interest rate that varies between 9,0% - 14,0% monthly (represented by the light gray cell). The variation in this value causes variation in the total net present cash flow value (represented by the dark gray cell). The results of the simulation conducted upon this model are given as percentiles in Table C17. Furthermore, Figure C1 shows the net cumulative cash flow movement of the project.

4.5.2.4.1 Results of cash flow risk analysis

A number of assumptions and predictions have been made and subsequently, two models have been produced in order to carry out cash flow risk analysis. One of them, as it is given in Table C14, is for the purpose of finding the accurate and appropriate fixed price of the project to be offered by Design-Builder A at the competitive tender. Five thousand of Monte Carlo iteration that is performed on this model finally has produced the resultant probability percentiles of a range of possible fixed prices, which is given in Table C16. However, the selection of the fixed price value among this range totally depends on the decision-maker's capability of risk taking. Here, it is assumed that Design-Builder A selects 18.860.721.720.000. -TL, which is the price value corresponding to 80% of risk level. This selected value is further effective on the other model that is developed to find out the net present value of the project with regards to the data produced so far. This model and its results are shown in Tables C15, C17 and Figure C1, respectively. The percentiles given in Table C17 show that the net present value of the project does never fall below the zero value. This means that the project's economic worth is positive with respect to the predictions and plans that have been developed up to here. In other words, this positive figure may turn to the negative if the predictions and assumptions do not come true and if the risk levels selected up to here do not become sufficient to tackle with the unforeseen risks. Nevertheless, risk analysis avoids the more terrible results of such a case.

4.5.2.5 Responding to risks

The project risks that have been identified, classified and analyzed in the preceding sections can be directed or kept under control by means of the risk retention, risk reduction and risk avoidance techniques. Risk transfer, i.e. allocation of the risks to a third party like a subcontractor is not a possible way for this kind of a project because Design-Builder carries the sole responsibility and liability against Owner in case of a fixed-price Design-Build contract system. In other words, Owner has nothing to do with the faults of the third parties; Design-Builder is liable to bear such difficulties.

Design-Builder A can apply the risk avoidance in two ways: withdrawing from the tender or increasing the contingency amount associated with the project price and increasing the duration. The first way is radical and can only be followed if it is anticipated that the project is not useful and sufficiently profitable for the company at macro level. The second way is somewhat related to the risk attitude of the company's senior management. Profit margin, cost values, activity durations and similar uncertain values of the risk analysis step can be increased to lower the risk level of the project. In spite of this, for the risk analysis results given in the previous sections, it is assumed that the computed fixed price, project duration and net present value are all appropriate with the Design-Builder A's objectives and for this reason, there is no need of increasing the fixed-price or project duration.

Risk retention is already inherent in Design-Builder A's approach to the competitive tender. The assumptions, predictions, risk levels and contingency allowances made throughout the previous risk management steps contain more or less the acceptance and retention of some portion of the risks. In other words, the predicted fixed price and project duration contains risk in itself; however Design-Builder A accepts this much of risk and its results.

Risk reduction technique is the most useful one among the risk response techniques due to the fact that it may increase the positive sides of the project in terms of money and time by reducing the effect of risks. Nevertheless, the whole reduction process may not be completed prior to the project execution. Rather, it is a continual process. For instance, a faster way of material procurement that is explored later during the construction, less defective designing during the preparation of the detailed design or directing the subcontractors for the completion of their works in advance of the planned duration are all the duration reducing activities. Risk reduction, in some sense, is the matter of the project management. In other words, all the managing actions taken to control cost, time and quality can be considered as risk reducing activities.

4.6 Step 4 – Evaluation and Awarding

In the invitation letters sent by the Owner's Representative to the Design-Build Firms for providing their attendances to the competitive tender, it is clearly implied that the Owner's evaluation criteria in the selection of the offered proposals will be 'duration, cost, architectural design' and the awarding method of the tender will be the 'weighted criteria'. By this way, the invited Design-Builders have prepared to the tender according to the Owner's directions.

Weighted Criteria is basically an awarding method used to evaluate the proposals in both qualitative and quantitative terms by means of ranking points. The procedure can be summarized as follows [54]:

- The proposals are scored out of 60 for their qualitative aspects, which are schedule and design, and then scored out of 40 for their quantitative aspect, which is cost or fixed-price. The reputation and the previous experience of the company are among the other affecting factors of the qualitative score.
- Afterwards, the qualitative and quantitative score of each proposal is added and the final scores out of 100 are found.
- The proposal having the highest point out of 100 wins the competition.

Table C18 represents the results of the competitive tender executed through the weighted criteria method between Design-Builder A, B and C. The results show that Design-Builder B wins the tender with the maximum total score, which is 90 although it gets the minimum price score by offering the maximum fixed-price. This shows that offering the minimum fixed-price is not enough to win the tender as in the case of classical lowest-cost awarding method.

CHAPTER 5

CASE STUDY II

5.1 Introduction

This chapter is devoted to a real Design-Build construction project that was undertaken and completed between the years 2001 and 2002 in Turkey. The project included the design and construction of a 3-storey police station building (basement, ground, 1st and 2nd floors) at the center of Diyarbakır, located on the southeastern region of the country. The project was a public procurement and accordingly, the whole activity was organized and managed by the Diyarbakır City Directorate of the State Public Works. The Design-Builder firm that won the bidding competition and subsequently carried out the project was a regional company named as DEN-KAR Ltd. Co.

Basic information that is introduced below is a summary of the story about this Design-Build project:

- Project Name: Diyarbakır/Center State Hospital Police Station Building Construction
- Employer: Diyarbakır City Governor
- Controller: Diyarbakır City Directorate of Public Works
- Design-Builder Firm: DEN-KAR Ltd. Co.
- Contract System: Design-Build

- Payment Method: Fixed-price
- Tender Invitation Date: 06.06.2001
- Tender Date: 15.06.2001
- Contract Date: 22.06.2001
- Preliminary Estimate Date: 21.02.2001 (with 2001 prices)
- Tender Estimate: 163.440.523.300. –TL (Value added tax is excluded)
- Successful Bid: 84.498.750.547. –TL (The lowest one)
- Provisional Surety Bond Amount: 4.910.000.000. –TL (3% of tender estimate cost)
- Final Surety Bond Amount: 5.075.000.000. –TL (6% of the successful bid)
- Final Surety Bond Date: 19.06.2001
- Site Delivery Date: 02.07.2001
- Construction Start Date: 28.08.2001
- Contractual Project Completion Date: 30.10.2001
- Contractual Duration of Project Completion: 131 days
- Actual Project Completion Date: 28.12.2001
- Actual Duration of Project Completion: 190 days
- Value Added Tax Rate: 18%
- Daily Penalty for Delay: 25.349.625. –TL (0,03% of the successful bid)

In order to provide visual clarification of the police station building, some architectural drawings provided from the designers of DEN-KAR Ltd. Co. are also given in Appendix D (Figure D1-D5). It should be emphasized that the design team of the Contractor Company has developed the final A/E design with regards to the simple floor drawings submitted by the Owner. This subject is further mentioned and discussed in the next sections.

5.2 Aims and Methodology of the Case Study

Fixed-price Design-Build contract system has started to be utilized more widely for executing the construction works of the Public Institutions of Turkey since 2000. The political tendency of the country towards becoming a member of the European Union and dependently, the new long-term preparation period officially commenced by the beginning of the 21st century for achieving this politic/economic target has been the driving factor of the increase in the number of Design-Build applications at the Turkish public projects. In this context, the State Bidding Law (No. 2886) has been changed according to the European norms and a new law named Public Bidding Law (No. 4734) has been approved by the Turkish Parliament (TBMM) in this year. Design-Build contract system will be the main project achievement method of the Turkish Public Institutions as this new law is officially started to be applied by the beginning of 2003. Unfortunately, many mistakes are being made in the public Design-Build projects realized during this reform period because of the deficiencies associated with the related laws and regulations and more important, due to the inexperience of the Public Owners and Contractors about this new system. These problems are being experienced more widely in the medium and small size projects, which are generally undertaken by the medium and small size local firms. This is the reason of selecting the Police Station Project as the second case study of the thesis. In other words, the application deficiencies and mistakes of Design-Build system in Turkish public practice will be investigated and tried to be clarified on this medium size construction project. This is the first aim of the study. The other purpose is to show the negative effect of the lack of risk identification and risk analysis in such a project executed at an economically risky period of Turkey during which two devaluations were experienced within the same year. While the first purpose of the case study will be achieved with a general look onto the project, the second purpose will be tried to be succeeded by directly applying risk identification and risk analysis on the project from the viewpoint of the Design-Builder firm, i.e. DEN-KAR Ltd. Co. and subsequently, comparing the gathered results with the actual project values and dates.

5.3 Bidding Issues of the Project

The method used for selecting the successful bidder at the competitive tender has been 'closed proposal system between the willing competitors' as it is named in the State Bidding Law (No. 2886). The bidding competition was made only 9 days after the Design-Builder firms had been informed about the tender. Obviously, 9 days of time is not enough for the firms to prepare for the tender properly and scientifically. Furthermore, as it is understood from the project documents, the invited Design-Builders were not informed sufficiently about the project for their preparation to the competition in such a short time. The Controller has given only a material list and simple drawings. It can be claimed that this much of information might be enough in a Design-Build project, but 9 days of time is not enough for exploring the Owner's needs and requests only based on this information. Accordingly, Design-Builders would not have been able to produce innovative designs and reliable cost/duration estimates during this limited time. And so, one of the most important advantages of the Design-Build system would not have been benefited.

The second fault made during the bidding period was the selection of the successful Design-Builder with respect to the lowest price offer criterion. The aim of Design-Build is not simply investigating the lowest bid just as in the case of the classical Design-Bid-Build applications. The design, quality, time schedule program and reputation/capacity of the companies should be the other selection criteria in Design-Build tenders. Otherwise, there is no meaning in utilizing this contract system. The worse, again as the documents show, Design-Builders have submitted their fixed-price offers without performing any serious tender preparation. This tendency cannot be described with only the insufficiency of the Owner's project request program and the shortness of the tender preparation period. The problems encountered in Turkish construction sector due to the economic crisis and dependent to this, the increased competition between the companies of this sector are the other causes of this deficiency. Naturally, the crisis conditions cause the unemployed construction contractors to submit their bids with closed eyes and this situation leads to high-risk undertakings.

DEN-KAR Ltd. Co. won the bidding competition with a fixed-price proposal of 84.498.750.547. –TL. This monetary value corresponds to a reduction of the tender estimate, which is 163.440.523.300. –TL, as much as its 48,30 percent. This is a huge risk both for the public Owner and more for the successful construction company. The intensity of this risk will be verified through the cost risk analysis in the next sections.

5.4 Contracting Issues of the Project

The contract and bidding specification signed between DEN-KAR Ltd. Co. and Owner (City Governor) are not proper for usage in a fixed-price Design-Build project. Rather, all these documents' content belongs to the unit-price Design-Bid-Build contract system. Some modifications and additions have been made in order to convert the documents to a suitable shape for their usage in the Police Station Project. For instance, there is a sentence added to the contract about design, which says 'all the design drawings will be done by the Contractor without any payment'. Strangely, this is the single sentence written about design throughout the contract. In other words, the contract has not been sufficiently, clearly and accurately prepared. However, the representatives of DEN-KAR Ltd. Co. have not opposed to such an improperly prepared contract or have not made any suggestions about converting it to a more precise form. Perhaps, the Company representatives have not even examined the contract content. This is possible for the reason that the main logic of many Turkish construction companies nowadays, because of strict competition, has reached to a point that 'the only important thing is getting the job; the rest is not important'. They are not concerned with or are not aware of the risks inherent in

Design-Build projects and also they have even no idea about risk analysis and management techniques.

The main risk allocation issues inherent in the contract is listed and described below:

- *Delay in construction*: The contractor (Design-Builder) is responsible for any delay in the delivery of the building to the owner in a completed position. In the contract, it is written that: 'Except for the time extension approved by the Controller, if the construction cannot be completed in time, 0,03% of the tender price will be cut for each passing calendar day as the delay punishment.'
- *Time extension*: Time extension is not provided except for the following conditions:
  - Owner or controller delays
  - Natural hazards disturbing or preventing the construction
  - Social events disturbing or preventing the construction such as legal strike, infectious disease or partial/general military mobilization

  In other words, contractor has no right for demanding any extension in the project duration except for the above conditions. Furthermore, the project duration determined and written in the contract also accounts for the inappropriate working period due to bad weather and official holidays; therefore, no time extension can be given for also such reasons.
- *Unforeseen change in quantity/scope of works:* In case of a change in quantity of works that is not predicted and included in the tender estimate, a modification corresponding to this change can be reflected to the tender estimate price up to 30 percent. The project duration can also be extended accordingly in the same context.
- *Material cost change:* Any change in material costs is not paid to the contractor. Furthermore, no advance payment is made for material procurement.
- *Accidents:* The contractor will be directly responsible for the accidents and their results that will occur during the construction.

5.5 Risk Study of the Project

5.5.1 Risk identification and classification

The risk density of a project is more or less dependent on its size, type and the surrounding conditions. Since the Police Station Project consists of the construction of a kind of three-storey official building, it can be considered as a medium size construction project. However, it should be emphasized that the Owner has demanded the third storey later (2^{nd} floor), i.e. after the bidding/awarding and contracting operations. The Owner, according to the contract clauses, was obliged to accept an appropriate change on the contracted fixed-price for compensating this quantity increase but this did not happen. Instead, the former scope of the project has been changed and in turn, the fixed-price was remained constant. The scope has been changed by excluding the site clearance and landscaping works from the Owner's request list and payment ratios table. These works comprised 11 percent of the whole project price value. This ratio was thought to be as sufficiently large for balancing the cost of the additional storey. Nevertheless, the conversations made with the representatives of DEN-KAR Ltd. Co. have shown that this had not come true. They claim that this quantity/scope change became one of the reasons of their profit decrease. For this reason, *quantity/scope change of the project* is taken as a risk to be used at the risk analysis step of the case study.

68 days in total have passed after the contracting date, i.e. 22.06.2001, for the Design-Builder Company's preparation of the architectural/engineering design projects and for the Owner's approval of them. After the consumption of 68 days, 63 days have remained for the completion of the whole construction site activities and delivery of the building to the Owner according to the contractual completion date, which was 30.10.2001. Naturally, 63 days of time did not become enough for finishing the whole construction works and unfortunately, the construction has been completed 122 days after the start of the site works, i.e. 28.12.2001. These facts

bring to mind the risks related to design, which are *delays in design* and *design changes*. The *defective design* risk is deliberately not included to this project's risks because three-storey building does not necessitate complex designing. Since, the Owner later demanded the construction of the additional third-storey, some changes might have been applied on the original design. For this reason, the *design changes* risk is included into the risk list.

The location of the construction site was on an area near the Diyarbakır State Hospital. Therefore, it was a secure region inside the city center. For this reason, *environmental restrictions, social events* and *natural hazards* risks are not taken into account for this project. However, *exceptionally inclement weather* and *accident* risks are thought to be effective more or less during the construction, because the construction activities have been carried out in autumn and winter seasons.

As far as it is concluded from the conversations arranged with the representatives of DEN-KAR Ltd. Co. d*ifficulties/delays in availability of materials, third party delays* and *unforeseen ground conditions* have been the other risky factors that affected the construction cost and duration. *Inadequate specifications* risk can also be added to these risks due to the reasons explained in the previous sections.

The risks specified up to here are of the general risks that can be encountered in most projects. There are also some other risks that have been experienced due to the conditions of Turkey and they have enormously affected the Police Station Project. They are *inflation, exchange rate fluctuation/devaluation* and *bureaucratic problems*. These risks caused the project cost to increase abnormally especially during the devaluation crisis experienced in November 2001, which was the second devaluation crisis experienced within the same year. The payments made to the Design-Builder prove this abnormal cost increase:

- 1.Payment (17.09.2001): 13.959.193.590. -TL (Value Added Tax is included)
- 2.Payment (15.10.2001): 16.950.449.360. -TL (VAT is included)

- 1. & 2. Payments' Cost Difference Payment (19.10.2001): 13.705.335.683. - TL (VAT is included)
- 3.Payment (13.11.2001): 32.542.844.943. -TL (VAT & Cost Difference is included)
- 4.Payment (12.12.2001): 17.604.736.712. -TL (VAT & Cost Difference is included)
- 5.Payment (28.12.2001): 30.476.177.672. -TL (VAT & Cost Difference is included)
- 6.Payment (13.02.2002): 28.863.225.168. -TL (VAT & Cost Difference is included)
- Total Payment: 154.127.312.700. - TL (VAT & Cost Difference is included)
- Total Payment: 130.616.366.700. - TL (VAT is excluded & Cost Difference is included)

The values given above show that the Owner had to finish the project with a total payment of 130.616.366.700. – TL although the contracted fixed-price was almost 2/3 of this value, which was 84.498.750.547. – TL. However, DEN-KAR Ltd. Co. claims that even this much of price increase has not sufficiently compensated the total construction cost and eventually, the project has been completed with only a net profit of approximately 4.000.000.000. - TL. But, what would have happened if the Owner had not been able to make the cost difference payments due to the State's possible disappointment of the cost difference payment decision!

All the risks that have been identified so far are further listed and classified in Table 5.1.

Table 5.1 Risk classification table

Risk No.	Risk Description	Type	Impact	Consequence
1	Changes in quantity/scope of work	Speculative	Project	Duration, Cost
2	Design changes	Pure	Project	Duration
3	Delay in design	Pure	Project	Duration
4	Third party delays and default	Pure	Project	Duration
5	Bureaucratic problems	Pure	Project	Duration, Cost
6	Exceptionally inclement weather	Pure	Project	Duration
7	Owner delays (unable to get approvals, lack of payment, delayed progress payments)	Pure	Company	Duration, Cost
8	Difficulties/delays in availability of materials, equipment and labor	Pure	Project	Duration, Cost
9	Inadequate quality of work and need for correction	Pure	Project	Duration, Cost
10	Unforeseen ground conditions	Pure	Project	Duration, Cost
11	Inflation	Speculative	Environmental	Cost
12	Exchange rate fluctuation/devaluation	Speculative	Environmental	Cost
13	Accidents	Pure	Project	Duration, Cost
14	Inadequate specifications	Pure	Project	Duration, Cost

5.5.2 Schedule risk analysis

The contractual starting date and deadline of the Police Station Project was 22.06.2001 and 30.10.2001, respectively. Time between these two dates constitutes a period of 131 days, which can be called as the contractual project duration. Nevertheless, the project has been completed in 28.12.2001, i.e. 59 days after the contractual deadline. The conversations arranged with the Design-Builder (Contractor Firm) show that the scope/quantity change, unexpected ground conditions and delay in design have been the main causes of this schedule overrun. Fortunately, the Owner has approved the Design-Builder's time extension request and therefore, no monetary delay punishment has been cut from the Design-Builder's payment certificates. However, this is not a common Owner behavior in Design-Build projects; at least such an amount of time extension is generally rejected for this size of building projects. Otherwise, schedule-shortening advantage of Design-Build contract system cannot be benefited.

In order to build up the schedule risk analysis model of the project and subsequently run Monte Carlo Simulation on the model; first of all, the project activities, activities' likely- minimum- maximum durations and network relationships between the activities are determined with respect to the Owner's simple drawings and request list. The risks identified in the previous section turn to be the effective agents in predicting the likely- minimum- maximum activity durations. Besides, experience and previous data are the other factors affecting the accuracy of these predicted values.

Next, activity names, likely durations and predecessors are entered into MS Project, simultaneously providing to the program the other schedule attributes such as the project start date and non-working days. The aim is to build the schedule plan and network of the project. Table 5.2 shows the summary schedule plan prepared with utilizing MS Project. As it can be seen at Table 5.2, the project ends at 30.11.2001. This means that the project can be completed in 162 days according to the normal schedule plan. This period is 31 days greater than the 131 days, which is the project duration negotiated and written in the contract. This time difference exhibits the inaccuracy of the contractually negotiated duration.

Figure 5.1 consists of a simplified version of the activity network produced by Critical Path – Activity on Node method in MS Project. Only the activity (task) numbers and the network relation in arrows can be observed in this Figure. The tasks shown in black boxes with black arrows make up the critical path.

Table 5.2 Time schedule program of the police station project

Task No.	Task Name	Likely Duration (days)	Start	Finish	Predecessors
1	Start	0	22.06.01	22.06.01	
2	Design	30	22.06.01	21.07.01	1
3	Excavation	5	12.07.01	16.07.01	2FS-10d
4	Levelling and rubble concrete	2	17.07.01	18.07.01	3
5	RC footings	8	22.07.01	29.07.01	4;2
6	Underground Insulation	1	16.08.01	16.08.01	10
7	Underground mechanical and electrical	1	17.07.01	17.07.01	3
8	RC basement floor slab	5	30.07.01	03.08.01	7;5
9	Backfill	1	17.08.01	17.08.01	6
10	Basement floor RC framework	12	04.08.01	15.08.01	8
11	Ground floor RC framework	12	18.08.01	29.08.01	10;9
12	First floor RC framework	12	30.08.01	10.09.01	11
13	Second floor RC framework	15	11.09.01	25.09.01	12
14	Internal and external walls	16	11.09.01	26.09.01	12;34
15	Door and window frames	2	25.09.01	26.09.01	14FS-2d
16	Plumbing	10	27.09.01	06.10.01	15
17	Electrical conduits	8	27.09.01	04.10.01	15
18	Undercoat plastering	10	02.10.01	11.10.01	15FS+5d
19	Roof works	10	26.09.01	05.10.01	13
20	Floor tiles	10	30.10.01	08.11.01	16;17;18;24;27
21	Wall tiles	10	12.10.01	21.10.01	16;17;18
22	Doors and windows	10	26.10.01	04.11.01	27FS-4d;15
23	Electrical wiring and panels	7	05.10.01	11.10.01	17
24	Fine plastering	10	12.10.01	21.10.01	16;17;18

Table 5.2 (cont'd)

Task No.	Task Name	Likely Duration (days)	Start	Finish	Predecessors
25	Basement floor ceiling painting	2	04.11.01	05.11.01	20FS-5d;24
26	Ground, first and second floors suspended ceiling	15	22.10.01	05.11.01	23;24
27	Internal painting	8	22.10.01	29.10.01	24
28	Ground and second floor ballustrades	8	31.10.01	07.11.01	22FS-5d
29	Joinery painting and glazing	7	31.10.01	06.11.01	22FS-5d
30	Benches	5	09.11.01	13.11.01	20;27
31	Sanitery fitting	6	22.10.01	27.10.01	21
32	HVAC units	6	01.11.01	06.11.01	26FS-5d;27
33	Electrical devices and armatures	5	06.11.01	10.11.01	21;26;27
34	Water container	4	16.08.01	19.08.01	10
35	External painting	6	08.11.01	13.11.01	18;28;19
36	External granite covering	8	14.11.01	21.11.01	35
37	Paving and kerbs	4	22.11.01	25.11.01	36
38	External tiles	5	26.11.01	30.11.01	37
39	Main service connections	8	22.11.01	29.11.01	36
40	Ataturk's bust	5	26.11.01	30.11.01	37
41	Finish	0	30.11.01	30.11.01	25;29;30;32;33;38;39;40;31

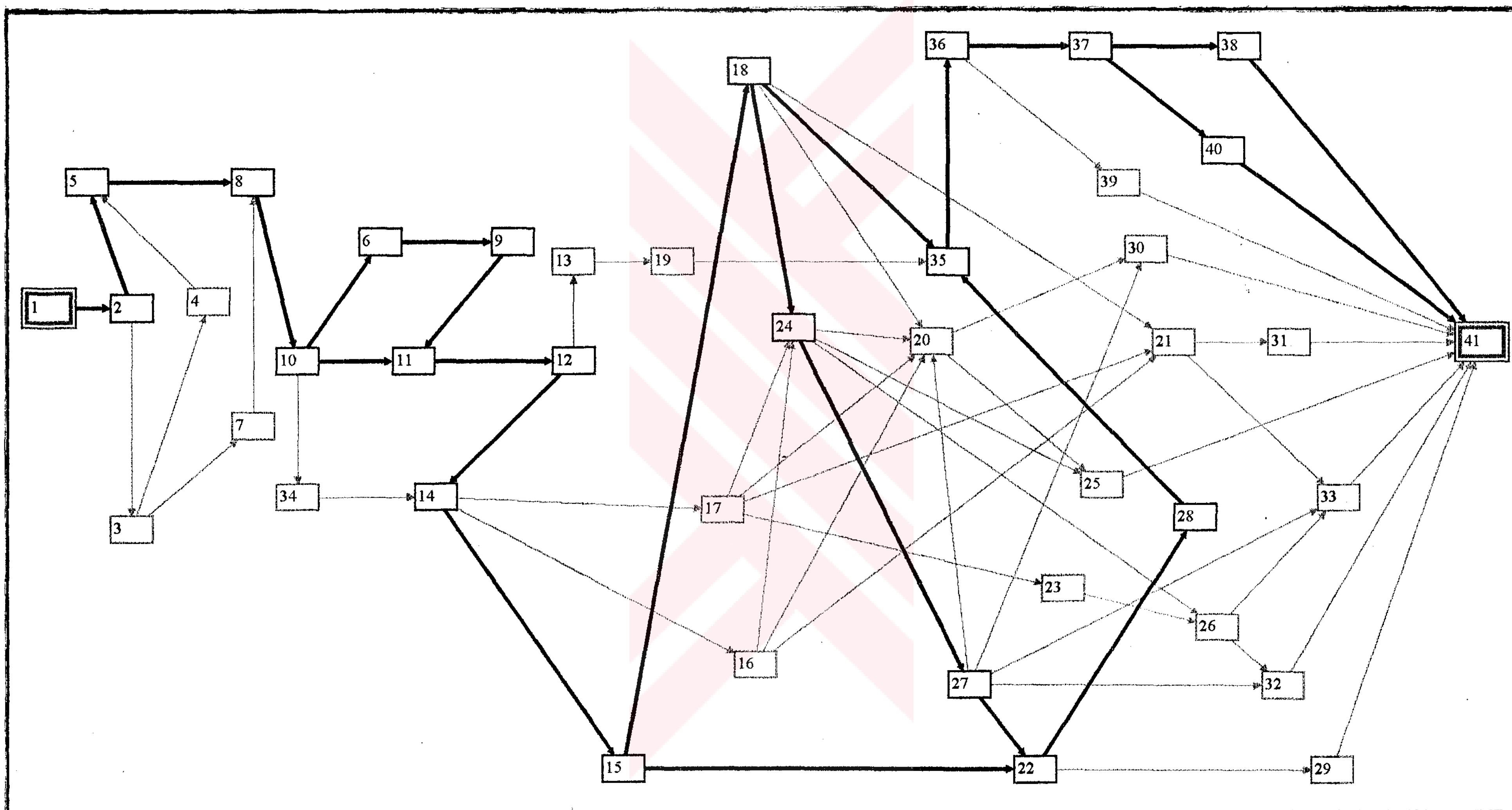

Figure 5.1 Activity network of the police station project

After building the schedule plan and network, schedule risk analysis model is prepared on MS Excel. The spreadsheet model is given in Table 5.3. Monte Carlo Simulation is carried out on this model by the commands of Crystal Ball, which is an Excel add-in risk analysis program that is also used in the previous case study. The seventh column of the model is composed of the cells constituting triangular probability distributions by which the likely- minimum- maximum activity durations are represented. No distribution is used at all for the activities of which the likely-minimum- maximum durations are equal. The cells of the subsequent columns are related to the seventh column's cells by mathematical formulas in order to build up the network logic on the model. The bottom cell of the 'late finish time' column is the cell at which the simulated project durations are accumulated and transferred to the resultant simulation diagrams in Crystal Ball. The results of the 5000 Monte Carlo iteration performed on the risk model are summarized in Table 5.4 and Figure 5.2. Table 5.4 consists of the risk percentiles and corresponding project durations. Figure 5.2 is the resultant cumulative frequency diagram of the simulation.

A detailed examination of the values presented in Table 5.4 shows that the contractual project duration, which is 131 days, is almost impossible to achieve because this value does not fall even into 0-100 percentage range. In contrast, 162 days, which is the likely project duration detected through the deterministic schedule planning falls into somewhere between 0-10 percentage range, somewhere closer to 10%. However, the fact is different: the project was completed in exactly 190 days and this value stands on 80-90 percentage range, somewhere closer to 90%. This situation proves that the project was sufficiently risky with regards to schedule or with another saying; the negative effects of the identified risks have been experienced up to a great extent during the project.

Table 5.3 Time schedule risk analysis spreadsheet model of the police station project

Activity Number (1)	Activity Name (2)	Predecessor (3)	Min. Duration (days) (4)	Likely Duration (days) (5)	Max. Duration (days) (6)	Simulated Duration-triangle distr. (days) (7)	Early Start Time (8)	Early Finish Time (9)	Late Start Time (10)	Late Finish Time (11)	Total Float (days) (12)	0=critical activity 1=non-critical activity (13)
1	Start		0	0	0	0,0	0,0	0,0	0,0	0,0	0,0	[redacted]
2	Design	1FS	20	30	60	36,7	0,0	36,7	0,0	36,7	0,0	[redacted]
3	Excavation	2FS-10d	2	5	20	9,0	26,7	35,7	26,7	35,7	0,0	[redacted]
4	Leveling and rubble concrete	3FS	2	2	2	2,0	35,7	37,7	35,7	37,7	0,0	[redacted]
5	Footings (formwork, reinforcement, concrete)	4;2FS	7	8	10	8,3	37,7	46,0	37,7	46,0	0,0	[redacted]
6	Underground insulation	10FS	1	1	1	1,0	63,3	64,3	63,3	64,3	0,0	[redacted]
7	Underground mechanical and electrical	3FS	1	1	1	1,0	35,7	36,7	45,0	46,0	9,3	[redacted]
8	Basement floor slab (rubble fill, slab concrete, RC footstall)	7;5FS	3	5	7	5,0	46,0	51,0	46,0	51,0	0,0	[redacted]
9	Backfill	6FS	1	1	1	1,0	64,3	65,3	64,3	65,3	0,0	[redacted]
10	Basement floor framework (formwork, reinforcement, mech.&elect. service connections, concrete-columns,curtain walls)	8FS	9	12	16	12,3	51,0	63,3	51,0	63,3	0,0	[redacted]
11	Ground floor framework (formwork, reinforcement, mech.&elect. service connections, concrete-columns, beams, stairs, slab)	10;9FS	9	12	16	12,3	65,3	77,7	65,3	77,7	0,0	[redacted]
12	First floor framework (formwork, reinforcement, mech.&elect. service connections, concrete-columns, beams, stairs, slab)	11FS	9	12	16	12,3	77,7	90,0	77,7	90,0	0,0	[redacted]
13	Second floor framework (formwork, reinforcement, mech.&elect. service connections, concrete-columns, beams, stairs, slab, roof slab)	12FS	12	15	20	15,7	90,0	105,7	125,3	141,0	35,3	[redacted]
14	Internal and external walls	12;34FS	13	16	21	16,7	90,0	106,7	90,0	106,7	0,0	[redacted]
15	Door and window frames	14FS-2d	2	2	2	2,0	104,7	106,7	104,7	106,7	0,0	[redacted]
16	Plumbing	15FS+5d	8	10	14	10,7	111,7	122,3	112,0	122,7	0,3	[redacted]
17	Electrical conduits	15FS+5d	6	8	11	8,3	111,7	120,0	140,7	149,0	29,0	[redacted]
18	Undercoat plaster (internal, external)	15FS+5d	8	10	15	11,0	111,7	122,7	111,7	122,7	0,0	[redacted]

Table 5.3 (cont'd)

Activity Number (1)	Activity Name (2)	Predecessor (3)	Min. Duration (days) (4)	Likely Duration (days) (5)	Max. Duration (days) (6)	Simulated Duration-triangle distr. (days) (7)	Early Start Time (8)	Early Finish Time (9)	Late Start Time (10)	Late Finish Time (11)	Total Float (days) (12)	0=critical activity 1=non-critical activity (13)
19	Roof works (chimneys, insulation, frame, tiles, gutters, pipes)	13FS	8	10	15	11,0	105,7	116,7	141,0	152,0	35,3	[redacted]
20	Floor tiles	16;17;18;24;27FS	8	10	14	10,7	142,0	152,7	161,0	171,7	19,0	[redacted]
21	Wall tiles	16;17;18FS	8	10	15	11,0	122,7	133,7	159,7	170,7	37,0	[redacted]
22	Doors and windows	27FS-4d;15FS	8	10	15	11,0	138,0	149,0	138,0	149,0	0,0	[redacted]
23	Electrical wiring and panels	17FS	5	7	10	7,3	120,0	127,3	149,0	156,3	29,0	[redacted]
24	Fine plastering	16;17;18FS	8	10	15	11,0	122,7	133,7	122,7	133,7	0,0	[redacted]
25	Basement floor ceiling painting	20FS-5d;24FS	1	2	2	1,7	147,7	149,3	175,3	177,0	27,7	[redacted]
26	Ground, first and second floors suspended ceilings	23;24FS	12	15	20	15,7	133,7	149,3	156,3	172,0	22,7	[redacted]
27	Internal painting	24FS	6	8	11	8,3	133,7	142,0	133,7	142,0	0,0	[redacted]
28	Ground and second floor balustrades	22FS-5d	6	8	10	8,0	144,0	152,0	144,0	152,0	0,0	[redacted]
29	Joinery painting and glazing	22FS-5d	5	7	10	7,3	144,0	151,3	169,7	177,0	25,7	[redacted]
30	Benches	20;27FS	3	5	8	5,3	152,7	158,0	171,7	177,0	19,0	[redacted]
31	Sanitary fitting	21FS	5	6	8	6,3	133,7	140,0	170,7	177,0	37,0	[redacted]
32	HVAC units	26FS-5d;27FS	5	6	8	6,3	144,3	150,7	170,7	177,0	26,3	[redacted]
33	Electrical devices and armatures	21;26;27FS	4	5	6	5,0	149,3	154,3	172,0	177,0	22,7	[redacted]
34	Water container	10FS	3	4	6	4,3	63,3	67,7	85,7	90,0	22,3	[redacted]
35	External painting	18;28;19FS	5	6	8	6,3	152,0	158,3	152,0	158,3	0,0	[redacted]
36	External granite covering	35FS	6	8	12	8,7	158,3	167,0	158,3	167,0	0,0	[redacted]
37	Paving and curbs	36FS	3	4	6	4,3	167,0	171,3	167,0	171,3	0,0	[redacted]
38	External tiles	37FS	4	5	8	5,7	171,3	177,0	171,3	177,0	0,0	[redacted]
39	Main service connections	36FS	6	8	12	8,7	167,0	175,7	168,3	177,0	1,3	[redacted]
40	Atatürk's bust	37FS	4	5	6	5,0	171,3	176,3	172,0	177,0	0,7	[redacted]
41	Finish	25;29;30;32;33;38;39;40;31FS	0	0	0	0,0	177,0	177,0	177,0	177,0	0,0	[redacted]

Table 5.4 Simulation percentiles of the police station project's schedule risk analysis

Percentile	Total Project Duration (days)
0%	152,4
10%	166,7
20%	170,3
30%	173,1
40%	175,6
50%	178,1
60%	180,9
70%	184,0
80%	187,7
90%	193,1
100%	213,1

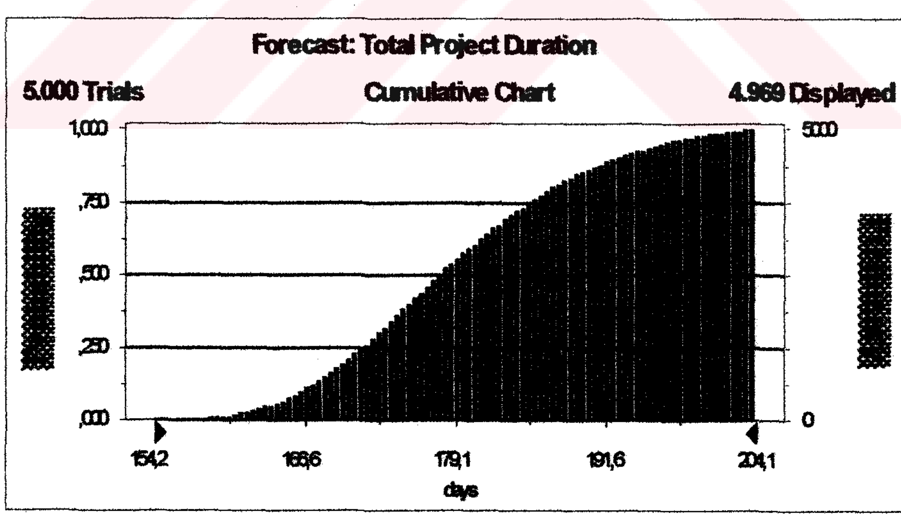

Figure 5.2 Resultant cumulative frequency diagram of the police station project's schedule risk analysis

A question may come into mind at this point: How would the Design-Builder select the appropriate and accurate project duration among the various values with different probability percentiles. Well, this is somewhat related to the risk attitude, experience, intuition and risk identification capability of the contractor and his staff. Since, the tender was awarded with regards to the lowest cost criteria, it seems that schedule risk analysis is useless; however, this is not true for accurately organized and implemented Design-Build tenders.

5.5.3 Cost risk analysis

The logic followed in preparing the cost risk analysis model of the Police Station Project is almost the same with the logic used in the cost risk analysis of case study 1. The prepared spreadsheet model for the Police Station Project is given in Table 5.5. Title names of the columns and their order within this table clearly present the steps undertaken for setting the model:

- First column: Production items that constitute the total price are grouped and numbered at the first column.
- Second column: Production item names that constitute the total price are listed at this column.
- Third column: Since unit price estimating technique is used in modeling, each production amount has to be measured based on a unit such as m, m^2 or kg, also that will be essential to the unit price units like m/TL, m^2/TL or kg/TL. In this sense, the third column is devoted to the production measurement units.
- Fourth column: The minimum, likely and maximum amount of each production item is estimated and recorded within this column. The estimation is processed based on the simple floor plans provided to the Contractor by the Owner prior to the tender. The minimum and maximum amount values,

which are the deviations from the likely value, are decided with experience and engineering judgment.

- Fifth column: The minimum, likely and maximum unit prices in TL currency are predicted by benefiting from the unit price lists published by the Ministry of Turkish State Public Works in 2001. Nevertheless, the price of 'design' item is estimated through investigating the market prices of 2001; 'electrical', 'mechanical' and 'overhead' prices are estimated through taking approximated percentages of the total construction price, i.e. electrical - 6%, mechanical -10%, overhead - 4%.
- Sixth column: The production amounts determined at the fourth column are qualified by means of triangular probability distributions within this column so that risk analysis program (Crystal Ball) randomly selects values from the minimum-maximum range in each iteration in an appropriate way with the probability distribution that is used.
- Seventh column: The unit prices determined at the fifth column are represented with triangular probability distributions at this column so that Crystal Ball randomly selects values from the minimum-maximum range in each iteration in an appropriate way with the triangular probability distribution that is used, in order to be utilized in price calculation.
- Eighth column: The values randomly selected from the sixth and seventh columns during Monte Carlo Simulation by Crystal Ball are multiplied and the results are summed up at the 'total price' cell at the bottom of this column. In other words, 'total price' cell is the forecast cell and the resultant simulation diagrams and tables are formed by the varying values stored within this cell.

Table 5.5 Cost risk model of the police station project

Item No (1)	Item Description (2)	Unit (3)	Amount (min-likely-max) (4)	Unit Price (min-likely-max) (million TL) (5)	Simulated Amount=A (Tri.distr.) (6)	Simulated Unit Price=B (TL) (Tri.distr.) (7)	Item Price=A*B (TL) (8)
1	*Design*	-	-	2.500,0 - 4.000,0 - 6.000,0	-	4.166.666.667	4.166.666.666,67
	Construction works						
2	Excavation	m3	350-370-400	0,7 - 3,0 - 7,0	373,33	3.566.667	1.331.555.555,56
3	Ready-mix concrete	m3	190-200-220	30,0 - 35,0 - 45,0	203,33	36.666.666,67	7.455.555.555,56
4	Rubble fill	m3	80-95-120	10,5 - 11,0 - 11,5	98,33	11.000.000,00	1.081.666.666,67
5	Paving, curbs, external ground tiles	m2	80-100-140	12,0 - 18,0 - 22,0	106,67	17.333.333,33	1.848.888.888,89
6	Half brick walls	m2	320-350-380	5,0 - 6,0 - 7,0	350,00	6.000.000,00	2.100.000.000,00
7	Full brick walls	m3	75-85-100	40,0 - 43,0 - 45,0	86,67	42.666.666,67	3.697.777.777,78
8	Roof tiles	m2	165-175-190	2,5 - 2,8 - 3,2	176,67	2.833.333,33	500.555.555,56
9	Angle roof tiles	m	32-35-40	1,0 - 1,1 - 1,3	35,67	1.133.333,33	40.422.222,22
10	Asphalt paper under roof tiles	m2	165-175-190	0,40 - 0,42 - 0,45	176,67	423.333,33	74.788.888,89
11	Glass wool, asphalt paper on roof slab	m2	165-175-190	1,60 - 1,75 - 2,00	176,67	1.783.333,33	315.055.555,56
12	Water proofing	m2	250-290-350	7,8 - 8,0 - 8,5	296,67	7.900.000,00	2.343.666.666,67
13	Formwork	m2	900-1300-1400	4,0 - 5,0 - 7,0	1.200,00	5.333.333,33	6.400.000.000,00

Table 5.5 (cont'd)

Item No (1)	Item Description (2)	Unit (3)	Amount (min-likely-max) (4)	Unit Price (min-likely-max) (million TL) (5)	Simulated Amount=A (Tri.distr.) (6)	Simulated Unit Price=B (TL) (Tri.distr.) (7)	Item Price=A*B (TL) (8)
14	Formwork scaffolding	m3	1500-1900-2000	0,70 - 0,72 - 0,75	1.800,00	723.333,33	1.302.000.000,00
15	Scaffolding	m2	500-660-750	0,75 - 0,80 - 0,90	636,67	816.666,67	519.944.444,44
16	Roof wooden frame	m2	165-175-190	12,0 - 12,8 - 13,5	176,67	12.766.666,67	2.255.444.444,44
17	Wooden door leaves	m2	55-60-70	21,0 - 22,0 - 24,0	61,67	22.333.333,33	1.377.222.222,22
18	Wooden door frames and casings	m2	30-35-45	18,5 - 19,5 - 21,0	36,67	19.666.666,67	721.111.111,11
19	Door and window frames	tn	0,75-0,83-0,95	450,0 - 480,0 - 530,0	0,84	486.666.666,67	409.935.555,56
20	Reinforcement steel	tn	20-24-30	260,0 - 290,0 - 350,0	24,67	300.000.000,00	7.400.000.000,00
21	Balustrades	kg	650-750-950	2,5 - 2,7 - 3,0	783,33	2.733.333,33	2.141.111.111,11
22	Flag mast	kg	80-100-140	1,25 - 1,40 - 1.60	106,67	1.416.666,67	151.111.111,11
23	Aluminium joinery	kg	1000-1200-1400	6,0 - 7,0 - 7,5	1.200,00	6.833.333,33	8.200.000.000,00
24	Zinc rainwater gutters	m	50-55-65	5,0 - 6,5 - 8,0	56,67	6.500.000,00	368.333.333,33
25	Chimney zinc covering	m	60-65-75	5,00 - 5,25 - 5,70	66,67	5.316.666,67	354.444.444,44
26	PVC rainwater pipes	m	75-80-90	1,80 - 2,20 - 2,70	81,67	2.233.333,33	182.388.888,89
27	Iron painting	m2	75-90-100	4,50 - 5,25 - 6,50	88,33	5.416.666,67	478.472.222,22

Table 5.5 (cont'd)

Item No (1)	Item Description (2)	Unit (3)	Amount (min-likely-max) (4)	Unit Price (min-likely-max) (million TL) (5)	Simulated Amount=A (Tri.distr.) (6)	Simulated Unit Price=B (TL) (Tri.distr.) (7)	Item Price=A*B (TL) (8)
28	Exterior painting	m2	450-500-600	1,5 - 1,8 - 2,2	516,67	1.833.333,33	947.222.222,22
29	Ceiling limewashing	m2	150-160-175	0,20 - 0,25 - 0,30	161,67	250.000,00	40.416.666,67
30	Wooden glossing	m2	90-95-105	1,5 - 1,7 - 2,0	96,67	1.733.333,33	167.555.555,56
31	Interior oil painting	m2	900-970-1100	3,0 - 3,7 - 4,5	990,00	3.733.333,33	3.696.000.000,00
32	Interior plastic painting	m2	280-300-350	1,5 - 1,7 - 2,0	310,00	1.733.333,33	537.333.333,33
33	Floor covering (mosaic tiles)	m2	140-145-160	6,0 - 6,8 - 7,5	148,33	6.766.666,67	1.003.722.222,22
34	Wall covering (faince tiles)	m2	170-180-200	8,0 - 9,0 - 9,5	183,33	8.833.333,33	1.619.444.444,44
35	Floor covering (ceramic tiles)	m2	25-30-40	6,0 - 7,0 - 9,0	31,67	7.333.333,33	232.222.222,22
36	Floor covering (33*33 granite tiles)	m2	400-460-600	20,0 - 30,0 - 35,0	486,67	28.333.333,33	13.788.888.888,89
37	Exterior wall covering (granite tiles)	m2	150-160-200	20,0 - 30,0 - 40,0	170,00	30.000.000,00	5.100.000.000,00
38	Stairs marble facing	m2	40-50-80	9,0 - 9,5 - 11,0	56,67	9.833.333,33	557.222.222,22
39	Marble window sills and parapets	m2	15-18-25	17,0 - 20,0 - 24,0	19,33	20.333.333,33	393.111.111,11
40	Exterior plastering	m2	500-520-600	2,5 - 2,7 - 3,0	540,00	2.733.333,33	1.476.000.000,00
41	Interior plastering	m2	1100-1250-1500	2,00 - 2,15 - 2,35	1.283,33	2.166.666,67	2.780.555.555,56

Table 5.5 (cont'd)

Item No (1)	Item Description (2)	Unit (3)	Amount (min-likely-max) (4)	Unit Price (min-likely-max) (million TL) (5)	Simulated Amount=A (Tri.distr.) (6)	Simulated Unit Price=B (TL) (Tri.distr.) (7)	Item Price=A*B (TL) (8)
42	Gypsium plastering	m2	900-970-1100	0,48 - 0,50 - 0,53	990,00	503.333,33	498.300.000,00
43	Levelling covering	m2	550-650-800	1,30 - 1,45 - 1,60	666,67	1.450.000,00	966.666.666,67
44	Cement floor covering	m2	150-190-250	1,0 - 1,5 - 2,5	196,67	1.666.666,67	327.777.777,78
45	Cement wall covering	m2	150-180-250	2,4 - 2,5 - 2,7	193,33	2.533.333,33	489.777.777,78
46	Window glasses (4+4 mm)	m2	80-100-130	24,0 - 25,0 - 27,0	103,33	25.333.333,33	2.617.777.777,78
47	Gypsium suspended ceiling	m2	300-350-400	7,0 - 8,0 - 9,5	350,00	8.166.666,67	2.858.333.333,33
48	Atatürk's Bust	-	-	1.500,0 - 2.000,0 - 2.500,0	-	2.000.000.000,00	2.000.000.000,00
49	*Overhead costs*	-	-	-	-	3.614.855.644,44	3.614.855.644,44
50	*Electrical works*	-	-	-	-	-	5.422.283.466,67
51	*Mechanical works*	-	-	-	-	-	9.037.139.111,11
						TOTAL PRICE :	117.390.724.888,89

After preparing the cost risk model as described above, Monte Carlo Simulation with 5000 iterations is conducted on the spreadsheet model. The simulation results have been arranged as probability percentiles in Table 5.6. For instance, the probability of completing the project at 113.108.376.545. –TL, 118.288.470.666. – TL and 121.886.316.971. – TL is 10%, 60% and 90%, respectively.

Table 5.6 Simulation percentiles of the police station project's cost risk analysis

Percentile	Total Price (TL)
0%	105.946.793.556
10%	113.108.376.545
20%	114.483.917.220
30%	115.577.957.495
40%	116.548.978.415
50%	117.382.403.874
60%	118.288.470.666
70%	119.140.881.073
80%	120.312.467.972
90%	121.886.316.971
100%	130.988.592.991

What do these values mean? They show that the bid of DEN-KAR Ltd. Co., which is 84.498.750.547. – TL is very low and risky. This bid value is even lower than the lowest price corresponding to 0% probability in Table 5.6, which is 105.946.793.556. – TL. Such a risky bid value has naturally converted the project from a profitable undertaking to almost an unprofitable one for the Contractor Firm; as the representatives of DEN-KAR Ltd. Co. have admitted that they had earned only a net profit of approximately 4 billions TL at the end of the project even though the Public Owner had tried to compensate the possible financial losses that might have been occurred due to two devaluations experienced throughout 2001. This official cost increase decision has caused the Contractor to be paid totally 130.616.366.700. – TL, i.e. 54.58% in excess of the contracted fixed price. It seems that even this much of increase could not save the Contractor, because the contracted fixed price value is already very low and risky. For example, if the Contractor's fixed price value had been 117.382.403.874. – TL (corresponding to 50% risk percentage in Table 5.6), the total payment would have been approximately 181.449.719.800. – TL, when the same cost increase ratio that is 54.58% is used. In such a case, the project would have been very profitable for the Contractor but the possibility of winning the tender would have been declined up to a great extent. For this reason, setting the balance between not failing at the tender and proposing a profitable fixed price bid in Fixed-Price Design-Build construction projects is very important for success.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The conclusions obtained throughout the thesis can be examined under four headings:

- Design-Build contract system
- Risk analysis and risk management
- Results of case study I
- Results of case study II

The total accumulation of the results supplied by the case studies mainly shows the applicability and necessity of risk analysis and risk management techniques in cost/duration estimating and controlling of contractual risks of construction projects contracted based on Fixed-Price Design-Build contract system. The literature survey and general discussion made through the background parts before performing the case studies build the infrastructure of the thesis. In other words, the results and information gathered from the literature survey not only clarify the various characteristics of Design-Build system and risk management separately but also submit the necessary data for connecting these subjects in order to carry out the succeeding case studies.

The following paragraphs include the results of the whole study in the direction of four headings mentioned above:

- *Design-Build contract system:*

Design-Build contract system, as the so-called project delivery method in which design and construction are both executed after tender under the responsibility of a single contractor, firm or consortium, is predicted to expand its application area in construction projects of developing countries like Turkey. The reason of this is the various advantages it provides: increased coordination among design and construction teams, concurrent execution of design and construction, single point of responsibility, less disputes and claims, innovation encouragement, shortened project duration, cost effectiveness, and etc. The main payment type (fixed-price, unit-price, cost plus) and the contract form utilized in a Design-Build project change the allocation balance of these advantages between owner and contractor (Figure 3.4). This is especially valid when the project risks affecting the duration and cost are considered. For instance, fixed-price payment method converts Design-Build system to a risky procedure for the contractors while creating a relaxed financial atmosphere for the owners. Simultaneously, two or three different payment methods can also be applied during the progress of the design and construction works in order to arrange a fair contractual environment for both parties. Furthermore, appropriate type of Design-Build system can be utilized according to the project complexity, size, risk density and preliminary design information at hand. For example, tendering can be made with negotiation or competition, or under one of the Design-Build methods named as Develop-Construct, DB-single-stage tender, DB-two-stage tender and Turnkey. The selection of the right payment type, contract form, tender method, evaluation/awarding technique and Design-Build type is crucial for achieving success in Design-Build construction projects. Furthermore, proper scope definition, proper identification of owner needs, good organization (Figure 3.3) and full application of modern management techniques are the other success factors. The most critical and important managerial tasks among these modern management techniques are planning, scheduling, estimating and cost management. Besides, risk management becomes the key success factor of Design-Build projects if it is integrated with the other critical management tasks.

The probable risks faced in Design-Build construction projects dominantly influence the cost, completion deadline, quality, design adequacy, operational adequacy and safety. Risk management system to be set up is more or less related to the identification and controlling of such risks.

Design-Build contract system has begun to be used almost in all types of construction projects by 1980's through producing different pretender and post tender strategies although it is generally used in industrial constructions under turnkey approach during 1970's. As the application area of Design-Build has expanded since 1980's, various institutions and consultant firms (FIDIC, JCT, ENAA, DBIA, etc.) from different developed countries like USA, UK and Japan have published standard Design-Build forms of contracts that are suitable for use in various types of construction such as building, infrastructure, transportation, power generation and water treatment projects. These standard forms of contracts provide an economical and convenient way for parties to contract without having applied for expensive lawyering to produce a contact for each new project.

Design-Build contract system is also an evolving system in Turkish public and private construction sectors even though it has a narrow past. The new Public Contract Law (No. 4734) approved by Turkish Parliament (TBMM) in 2002 instead of the old State Bidding Law (No. 2886) accepts the Design-Build system as the general project realization method of public projects. However, Turkish contractors may experience some difficulties in Design-Build projects at the beginning due to the inherent uncertainty, weak design capability, high tendering costs, difficulties in cost/time estimating and increased necessity to quality control.

- *Risk analysis and risk management:*

The risks inherent in construction projects affect the parties differently throughout the project progress (Figure 2.1). These risks may vary according to the conditions and characteristics of the project but risk lists that have been produced so far have almost similar contents when the consequences of risks are taken into account. The cost, duration, quality, operationality and safety are the major project aspects that are affected from various kinds of risks. Past records can be helpful up to a certain extent in identifying the inherent risks of the coming projects due to the uniqueness of each project. Then, managing the risks in construction projects turns to be also a matter of common sense, analysis, judgment, intuition, experience, gut feel and willingness.

Risk management consists of systematic efforts for identifying, classifying, analyzing the risks and responding to them. The level of success at construction projects is related to the amount of risk management undertaken at today's competitive conditions of the construction sector. The appropriate risk identifying procedures have to be applied as early as possible during the preliminary design stage and the risk management system set up for achieving the project objectives should be updated throughout the project stages. Otherwise, disastrous effects of the risks cannot be avoided. Risk classification provides a more comprehensive risk and project view. The importance of risk analysis is that it shows what happens if the project does not proceed according to the plan due to the potential risks and warns the decision-maker or manager about the necessary responses to cope with risks. Furthermore, it captures all the feasible options and analyses the various possible outcomes of any decision.

Stochastic risk models and analysis techniques are becoming more popular among project managers and decision-makers because the variables in a stochastic risk analysis model can be represented by probabilistic terms or distributions rather than single values as in the case of deterministic risk models and analysis techniques such as sensitivity analysis. For instance, Monte Carlo simulation is a very widely used stochastic risk analysis technique. It is particularly useful when processes or events are too complex to be solved analytically. The power of Monte Carlo simulation in schedule, cost and cash flow risk modeling and analysis has been tested through the case studies I and II.

The last action of risk management is responding to risks. The results of the preceding risk management steps are evaluated and accordingly, the strategies to cope with risks are determined during this step. Risk attitudes of the decision-makers also become effective at this step.

Cost risk modeling, schedule risk modeling and cash flow risk modeling have great importance for assessing the effects of the risks quantitatively and making decisions to struggle against risks in construction projects. It is almost impossible to perform risk simulations on a risk analysis model without using computer programs. The best example is Monte Carlo simulation, which necessitates at least hundreds of iterations even for simple models. For this reason, manual application of Monte Carlo simulation is inconsistent while computer programs are capable of doing the same job faster, more precisely and with much more running preferences. Furthermore, such programs provide an easy and effective environment for data entrance and worksheet modeling. This is shown on Crystal Ball risk analysis software in the case studies I and II.

- *Results of case study I:*

A hypothetic Fixed-Price Design-Build project that is developed based on a real phenomenon experienced by a Turkish State Bank (T. C. Ziraat Bankası) during its structural reform period (preparation for privatization) has been carried out in case study I. The capability and applicability of risk analysis and risk management techniques throughout the tender preparation stages, i.e. during cost estimating and scheduling processes have been inspected from one of the contractors' point of view, who is invited to the bidding competition. Furthermore, the whole pretender process of the project, from the owner's decision on the project till the evaluation and awarding of the tender proposals, has been described in detail in order to present and distinguish the specific characteristics of Design-Build system.

Monte Carlo simulation has given excellent results during schedule, cost and cash flow risk analyses. Moreover, MS Excel and Crystal Ball utilized in developing the spreadsheet risk models have been capable of producing versatile solutions. However, the accuracy of the risk analysis results was mainly limited with the reliability of the used data, proper clarification of the owner needs and proper identification of risks.

FIDIC' s (International Federation of Consulting Engineers) Design-Build standard form of contract has been used as the base contract model in the case study. For this reason, risk allocation has been discussed according to the clauses of this contract form and the contractor's risk identification has been performed with respect to the results of this discussion. It was observed that FIDIC' s Design-Build standard form of contract has a logical and suitable risk allocation content. Besides, it was flexible and open to modification for the varying conditions of construction projects. As a conclusion, it can also be used in public and private Design-Build construction projects of Turkey.

The evaluation and awarding of the invited contractors' tender proposals have been realized by using weighted criteria method. The proposals have been evaluated in both qualitative and quantitative terms by means of ranking points of weighted criteria method. The process has shown that offering the minimum fixed-price is not enough to win the bidding competition as in the case of classical lowest-cost awarding method.

- *Results of case study II:*

In case study II, a real construction project from Turkey tendered and executed under Fixed-Price Design-Build contract system has been examined from the Contractor Firm's point of view. The work was the construction of a three-storey police station building (basement, ground, 1st and 2nd floors) and therefore, it was a medium size public project.

The case study has been carried out at four steps:

- Giving basic information about the Police Station Project
- Discussing the bidding issues
- Discussing the contracting issues
- Performing risk study (risk identification/classification, schedule risk analysis, cost risk analysis)

The discussion parts of the case study have shown that there exist deficiencies and mistakes in the application of Design-Build system in this Turkish public practice. First of all, 9 days of period given to the invited contractor firms by the owner (City Governor) for their preparation for the tender was not enough. Second, the invited contractors were not informed sufficiently about the project for their preparation to the bidding competition in such a short time. The controller has given only a material list and simple floor drawings. For these reasons, contractor firms were not able to produce innovative designs and reliable cost/duration estimates during this limited time with this much of information. As a conclusion, one of the most important advantages of the Design-Build system was not benefited.

The next fault made during the bidding period was the selection of the successful contractor with respect to the lowest price offer criterion. The aim of Design-Build is not simply investigating the lowest price just as in the cases of the classical Design-Bid-Build applications. The design, quality, time schedule program and reputation/capacity of the companies should be the other evaluation/awarding criteria in Design-Build tenders. The worse is that the conditions of economic crisis and dependent to this, the increased competition between the companies of this sector cause the construction contractors to submit their bids with closed eyes and this situation leads to high-risk undertakings as in this case of Police Station Project.

The other deficiency detected through the inspection of the project documents is that the utilized contract form did not have a proper content for usage in such a Fixed-Price Design-Build project. In contrast, the content of the contract form belongs to the Unit-Price Design-Bid-Build contract system. Some modifications and additions have been made in order to convert the documents to a suitable shape for their utilization. However, the representatives of the contractor firm have not even opposed to this situation nor made any suggestions related to the contract form. The main reasons of this are the inexperience of the firm and the strict competition between the companies of the construction sector.

The risk study of the Police Station Project has been performed in three steps: risk identification/classification, schedule risk analysis and cost risk analysis. Schedule risk analysis has shown that the contractual project duration, which was 131 days was only a big mistake because it was found that the project could be completed in 162 days according to the normal (deterministic) schedule plan (Table 5.2) and completion within 131 days was not possible according to the schedule risk analysis results (Table 5.4). The project was actually completed exactly in 190 days and this value falls on 80-90 risk percentage range in Table 5.4. Besides, 162 days was falling into somewhere between 0-10 percentage range. This situation proves that the project was sufficiently risky with regards to schedule or with another saying; the negative effects of the identified risks have been experienced up to a great extent during the project. More important, these results show the necessity of schedule risk analysis in this kind of projects. The results of cost risk analysis have also presented similar conclusions and have shown the necessity of cost risk analysis before the tender in Fixed-Price Design-Build projects. The results have shown that the bid of the contractor, which was 84.498.750.547. – TL was very low and risky. This bid value is even lower than the lowest price corresponding to 0% probability in Table 5.6. Such a risky bid value has naturally converted the project from a profitable undertaking to almost an unprofitable one for the contractor firm even though the public owner had tried to compensate the possible financial losses that might have been occurred due to the devaluations experienced in 2001. As a conclusion, setting the balance between not failing at the tender and proposing a profitable fixed price bid value after performing cost risk analysis in fixed price Design-Build construction projects is crucial for success.

6.2 Recommendations

This study is carrying the duty of attracting the attention of the construction sector's owners, contractors and researchers onto the importance and necessity of risk analysis and risk management techniques particularly during tender preparation (cost/duration estimating) stages of the Fixed-Price Design-Build projects. The studies that might be conducted on this area in the future can possibly cover the application of risk management techniques at the project realization stages of Fixed-Price or Cost-plus Design-Build construction projects. Furthermore, investigations can be carried out for identifying the appropriate project characteristics or management/organization models for successful public sector Design-Build projects in Turkey. Such researches would be necessary and useful as the utilization of Design-Build contract system evolves in Turkish public construction projects by the beginning of 2003, which is the starting year of the official application of the new Public Bidding Law (No. 4734) in public projects.

The universities and sector's related institutions can conduct researches in order to find the ways of increasing the experience and knowledge of Turkish companies on the subjects of schedule planning, risk analysis, risk management and relevant software. Turkish construction companies are already very experienced and have wide volume of data from previous projects. This would create an advantage and easiness in the application of risk analysis and risk management in their future projects.

Turkish public (state) owners and national consultant organizations can produce standard forms of contracts (for Design-Build or other contract systems) that include clauses which convert the schedule planning, risk analysis and risk management to compulsory activities for the contractors. These standard forms of contracts will naturally provide the specific country characteristics to be taken into account and this will lead to more appropriate environments for realizing successful projects.

Risk analysis and risk management cannot be considered as independent managerial tasks from quality assurance system and total quality management in construction projects. This is mainly due to the fact that there exist various risks that influence the quality of construction. For this reason, future works may also pursue the goal of investigating the quality-risk relationship in construction projects. Such researches would probably open new horizons with regards to the application of quality assurance system and total quality management in these projects.

REFERENCES

[1] Pilcher, R. (1973). *Appraisal and control of project costs*. London: McGraw Hill.

[2] Flanagan, R., & Norman, G. (1993). *Risk management and construction*. Cambridge: University Press.

[3] Crystal Ball 2000 Software (2002): *http//www.decisioneering.com/*

[4] Edwards, P. J., Bowen, P. A. (1999). Risk and risk management in construction projects: concepts, terms and risk categories re-defined. *The Journal of Construction Procurement*, Vol. 5 No. 1: http://www.fbe.unsw. edu. au/ jocp/ vol5no1.htm#risk

[5] Evans, J. R., & Olson, D. L. (1998). *Introduction to simulation and risk analysis*. New Jersey: Prentice Hall, Inc.

[6] Vaughan, E. J. (1997). *Risk management*. New York: John Wiley.

[7] Construction Risk Management Library on Internet (2001): http://www.riskdriver.com/ie/practices/practices.html

[8] Porter C.E. (1981). *Risk allowance in construction contracts*. Manchester: M. Sc. Thesis, University of Manchester (UMIST).

[9] Healy, J. R. (1982). Contingency funds evaluation. *Transaction of American Association of Cost Engineers*, B3.1-B3.4

[10] Barrie D., & Paulson B. (1992). *Proffessional construction management*. New York: McGraw Hill.

[11] Perry, J.G., Hayes R.W. (1985). Risk and its management in construction projects. *Proceedings of Institution of Civil Engineers*, **78**, 499-521

[12] Bufaid, A.S. (1987). *Risks in construction industry: their causes and their effects at the project level.* Manchester: Ph. D. Thesis, University of Manchester (UMIST).

[13] Burcu, A., Martin, F. (1998). Factors affecting contractors risk of cost overburden. *Journal of Management in Engineering (ASCE)*, **14**, 67-76

[14] Kartam N.A., Kartam S.A. (2001). Risk and its management in the Kuwaiti construction industry: a contractors' perspective. *International Journal of Project Management,* **19**, 325-335

[15] Elmas, D. (1996). *Risk analysis of construction projects based on unit prices under inflationary conditions.* M. Sc. Thesis. Ankara: Middle East Technical University (METU).

[16] Edwards P. J., Bowen P. A. (1998). Risk and risk management in construction: towards more appropriate research techniques. *The Journal Of Construction Procurement,* **4**, 103-115

[17] Griffis, F.H., & Farr, J.V. (2000). *Construction planning for engineers.* Singapore: McGraw Hill.

[18] Mark K., Victor S. (1998). Comparison of U.S. Project delivery systems. *Journal of Construction Engineering and Management (ASCE)*, **124**, 435-444

[19] Issaka N., Adrian T. (1994). Building procurement by Design and Build approach. *Journal of Construction Engineering and Management (ASCE),* **120**, 243-256

[20] Thompson, P. (1981). *Organization and economics of construction.* London: McGraw Hill.

[21] Gürsel, A. (1998). *Risk perception and trends of Turkish construction companies.* M. Sc. Thesis. Ankara: Middle East Technical University (METU).

[22] Kangari, R. (1995). Risk management perceptions and trends of U.S. construction. *Journal of Construction Engineering and Management (ASCE)*, **121**, 422-429

[23] Tevfik, A.T. (1997). *Risk analizine giriş.* İstanbul: Alfa Basın Yayın Dağıtım.

[24] Elkington, P., Smallman, C. (2002). Managing project risks: a case study from the utilities sector. *International Journal of Project Management*, **20**, 49-57

[25] Cooper, D. & Chapman, C. (1987). *Risk analysis for large projects-models, methods and cases*. UK: John Wiley.

[26] Chapman, C. & Ward, S. (1997). *Project risk management risk management processes, techniques and insights*. UK: John Wiley.

[27] Tummala, V.M.R., Burchett, J.F. (1999). Applying risk management process (RMP) to manage cost risk for an EHV transmission line project. *International Journal of project management*, **17**, 223-235

[28] Hertz, D.B. & Thomas, H. (1983). *Risk analysis and its applications*. UK: John Wiley.

[29] Charette, R.N. (1989). *Software engineering risk analysis and management*. USA: Intertext Publications – McGraw Hill.

[30] Carter, B., Hancock, T., Morin, J., Robin, N. (1994). *Introducing RISKMAN: the European project risk management methodology*. UK: NCC Blackwell Limited.

[31] Tummala, V. M. R., Nkasu, M. M., Chuah, K.B. (1994). A systematic approach to risk management. *Journal of Mathematical Modeling and Scientific Computing*, **4**, 174-184

[32] Edwards, L. (1995). *Practical risk management in the construction industry*. Glasgow: Thomas Telford Publications.

[33] Thompson, P.A. & Perry, J.G. (1992). *Engineering construction risks*. London: Thomas Telford.

[34] Kazan, M. Ş. (1996). *Management of political risks in public non-building construction projects*. M. Sc. Thesis. Ankara: Middle East Technical University (METU).

[35] Kangari, R., Riggs, L.S., (1989). Construction risk assessment by linguistics. *IEEE Trans. Eng. Manag.*, **36**, 126-131

[36] Blank, L.T. & Tarquin, A. J. (1989). *Engineering economy*. Singapore: McGraw-Hill.

[37] Tutorial of Project Risk Analysis Software (2001): *www.katmarsoftware.com*

[38] Wall, D. M. (1997). Distributions and correlations in Monte Carlo simulation. *Construction Management and Economics*, **15**, 241-258

[39] Akintoye, A.S., MacLead, M.J. (1997). Risk analysis and management in construction. *International Journal of Project Management*, **15**, 31-38

[40] Al-Bahar, J.F., Crandall, K.C. (1990). Systematic risk management approach for construction projects. *Journal of Construction Engineering and Management (ASCE)*, **116**, 533-546

[41] Smith, K. A. (2000). *Project management and teamwork*. USA: McGraw-Hill.

[42] Rothenberg, J. (1989). *The nature of modeling, artificial intelligence, simulation and modeling*. New York: John Wiley.

[43] Grey, S. (1995). *Practical risk assessment for project management*. UK: John Wiley & Sons.

[44] Dawood, N. (1998). Estimating project and activity duration: a risk management approach using network analysis. *Construction Management and Economics*, **16**, 41-48.

[45] Işık, A. (1999). *Mühendislik ekonomisi*. Ankara: Bizim Büro Basımevi.

[46] Halpin, D.W., & Woodhead, R.W. (1998). *Construction management*, John Wiley & Sons, Inc.

[47] Bakır, N.N. (1997). *Course notes for practical aspects of construction planning and management*. Ankara: Middle East Technical University (METU).

[48] Özdoğan, İ. (1996). *Risk management of build-operate-transfer (BOT) projects in developing countries*. M. Sc. Thesis. Ankara: Middle East Technical University (METU).

[49] Anumba, C. J., Evbuomwan, N. F. O. (1997). Concurrent engineering in design-build projects. *Construction Management and Economics*, **15**, 271-281

[50] Turner, J.R., Simister, S.J. (2001). Project contract management and a theory of organization. *International Journal of Project Management*, **19**, 457-464

[51] Franks, J. (1992, June). Design and build tendering-do we need a code of practise? *Chartered Builder*, pp. 8-10

[52] Marshall, J. (1992, June). Construction Industry – its ailments and cures. *Chartered Builder*, pp.11

[53] Akintoye, A. (1994). Design and build: a survey of construction contractors'views. *Construction Management and Economics*, **12**,155-63

[54] Beard, J. L, Loulakis, M.C., & Wundram, E.C. (2001). *Design-build: planning through development*. New York: McGraw Hill.

[55] Konchar, M., Sanvido, V. (1998). Comparison of U.S. project delivery systems. *Journal of construction engineering and management (ASCE)*, **124**, 435-444

[56] Ndekugri, I., Turner, A. (1994). Building procurement by design and build approach. *Journal of Construction Engineering and Management (ASCE)*, **120**, 243-256

[57] The Chartered Institute of Building. (1988). *Design and Build code of estimating practice supplement no.2.*

[58] Tam, C.M. (2000). Design and build on a complicated redevelopment project in Hong Kong: the happy valley racecourse redevelopment. *International Journal Of Project Management*, **18**, 125-129

[59] Ernzen, J., Schexnayder, C. (2000). One company's experience with design/build: labor cost risk and profit potential. *Journal of Construction Engineering and Management (ASCE)*, **126**, 10-14

[60] Ling, Y.Y., Lau B.S.Y. (2002). A case study on the management of the development of a large-scale power plant project in East Asia based on design-build arrangement. *International Journal of Project Management*, **20**, 413-423

[61] Türk Müşavir Mühendis Mimarlar Birliği (2001): *www.tmmmb.org.tr*

[62] CII Impact Report. (1980). *Assessment of Construction Industry Project Management Practices and Performance.*

[63] Loulakis, M.C., Shean, O.J. (1996). *Risk Transference in Design-Build Contracting.* Construction Briefings, 2nd series, 96-5, Federal Publications, April 1996, endnote 5, p.2

[64] Loulakis, M.C. (1999). Design-build: does it guarantee project success? Construction Risk Management Library on World Wide Web (Vol.1, No.8): *http://www.constructionrisk.com/newsletter/articles/article8.htm#1*

[65] Songer, A.D., Molenaar, K.R. (1997). Project characteristics for successful public-sector design-build. *Journal of Construction Engineering and Management (ASCE)*, **123**, 34-40

[66] Songer, A.D., Molenaar, K.R (1998). Model for public sector design-build project selection. *Journal of Construction Engineering and Management (ASCE)*, **124**, 467-479

[67] Chan, A.P.C., Ho, D.C.K., Tam, C.M. (2001). Design and build project success factors: multivariate analysis. *Journal of Construction Engineering and Management (ASCE)*, **127**, 93-100

[68] Stager, D.K. (1995). Organizing and managing a finance-design-build project in Turkey: fourth roebling lecture. *Journal of Construction Engineering and Management (ASCE)*, **122**, 199-204

[69] T.C. Bayındırlık ve İskan Bakanlığı (2001): *www.bayindirlik.gov.tr*

[70] T.C. Devlet Su işleri (2001): *www.dsi.gov.tr*

[71] International Federation of Consulting Engineers, FIDIC. (1995). *Design-build and turnkey 1st Ed (Orange Book).*

[72] Harris, F. & McCaffer, R. (1995). *Modern construction management.* Cambridge: University Press.

[73] HarperCollins Publishers. (1988). *Collins cobuild essential English dictionary.*

APPENDIX A

CASE STUDY I - DESIGN MODEL EXPLANATION

The office building selected as a model for the tender proposal is a three storey local: basement floor, first floor and a half floor. The office has been used as a bank office by Ziraat Bank for over 15 years and now it needs a complete repair and alteration. It is not an independent building; i.e. it is located at the base and first (entrance) floors of a six-storey business building. Its net floor area is approximately 700 m^2.

The banking service will be carried out at the first floor and the half floor according to the model. The basement floor has been designed as an archive, depot, money safe, WC and kitchen. Except for these; electric power generator, electric control panels and central HVAC (heating, ventilating, air conditioning) control units have been located at this floor. The first floor consists of the manager room; staff working desks, easy chairs, armchairs, counter tables and cashier dividing. The half storey also includes working desks, counter tables, chairs and cashier's dividing.

There is only one door opening to the bank for security reasons and it is the double-acting bank entrance door at the first floor. All the storeys are connected to each other by stairs. The stairs connecting the first floor to the half storey is used by personnel and customers, whereas the staircase providing connection between the base floor and the first floor is used only by personnel. The banister rails of the stairs and the half floor are made of stainless steel and single mica glasses. The bank entrance door is composed of two double-acting doors and the second door acts as a wind door. The ATM (automatic money) machine is located just near the entrance door.

No guardrails have been used for protecting the window glasses because unbreakable emergency glasses have been used in all windows. All the outer window glasses are heat and noise insulated double-glazing. The inner doors and show case glasses are not heat insulated and they are single glazing.

All the walls are oil painted over plaster finish and the color of the paint is dull white. The ceiling of the basement floor is plastic painted and the ceilings of the first floor and the half storey are covered with rock wool suspended ceilings. The HVAC and lighting system elements are hidden within these suspended ceilings. Carton-pierre is fitted to the suspended ceilings at the boundaries. The base slab of the first floor is covered with 33*33 cm colored mosaic tile, whereas the base slabs of the first floor and the half storey are covered by travertine appeared 33*50 cm ceramic. The stairs are also covered with this material. Its color is light pink.

The doors, showcases and windows are all framed with the first class aluminum joinery. Natural dull anodized silver gray colored aluminum is used in all joineries. The exterior walls of the office building are covered with mechanically suspended gray granite tiles. The lighting advertisement panel of the bank is the same as the other offices of Deutsche Bank.

APPENDIX B

CASE STUDY I - RISKS AND CONTRACT CLAUSES

This section is formed for the purpose of discussing the FIDIC' s design-build contract form in terms of the project risks that are specified in Table A2. The scope of this discussion provides information about how risks are allocated within the contract clauses.

<u>*Risk 1 - Defective design*</u>: Defects in design projects and documents are under the liability of Design-Builder. This is mentioned in the clauses 5.2 and 5.8. For instance, the clause 5.8 says: *If defects are detected in design projects and documents; defects in projects and their effects on construction will have to be repaired and compensated by Design-Builder.*

<u>*Risk 2 - Design changes*</u>: No change can be made in design without the approval of Owner's Representative. If the change request is accepted and approved by Owner's Representative, Design-Builder will be liable for revising the cost offer and the schedule accordingly. If the new offer is found logical, Owner's Representative negotiates with Design-Builder about the revised cost and schedule modifications. Unless any consensus was supplied, Owner's Representative would solve the problem fairly, logically and within the contract clauses. The 'consensus' or 'negotiation' remains an open door on how the 'design changes' risk is shared between Owner and Design-Builder. This situation creates a fuzzy environment

Risk 3 - Delays in design: Since the responsibility of preparing the design projects belongs to Design-Builder, probable delays in design completion is not the concern of Owner unless the delay is caused due to the following reasons:

- Social events (already ineffective on design activities) (Clause 19.1)
- Natural hazards (already ineffective on design activities) (Clause 19.1)
- Any interference occurred by the Owner's Requests (Clause 8.3)

In any case of these situations, Design-Builder has the right to request time extension from Owner's Representative.

Risk 4 - Subcontractors' default: This risk is completely under the responsibility of Design-Builder (Clause 4.5). This is normal because no contractual relationship exists between the contractor and owner and for this reason; only Design-Builder has the power of controlling the activities of subcontractors. Although this is a pure duration risk from the viewpoint of Design-Builder, the contract conditions between Design-Builder and subcontractor determine the cost risk level of Design-Builder. In other words, this risk may also become a cost risk with respect to the contract conditions between Design-Builder and subcontractor.

Risk 5 - Fluctuation in labor productivity: This risk is not the concern of Owner. Design-Builder is fully liable to take the necessary precautions for tackling it. (Clause 17.3 & 17.5)

Risk 6 - Delay in resolving disputes: An independent commission whose members are appointed by the participants of the contract solves the disputes between Owner and Design-Builder. This commission is responsible for finding solutions to the problems in maximum 56 days (Clause 20.4). It is obligatory for the parties to act in the direction of the commission's decisions. This issue is risky for both Owner and

Design-Builder. Late resolution of the disputes may lead to cost and time overruns. Therefore the premiums associated with this risk should be considered in detail.

Risk 7 - Owner Delays: Clause 13.7 clarifies what happens if Owner delays progress payments: *Design–Builder deserves of being repaid by Owner at the unpaid amount with the interest calculated through the contractually specified discount rate*.

At the first instant, it seems that this issue is not a risk for Design-Builder. However, this is valid only in project level. However, it is an absolute risk in company level for Design-Builder. It may also lead to time overruns and subsequently, disputes occur between the parties.

Owner's approval delays are the concern of Owner, i.e. Owner's Representative has to submit the Owner's approvals to Design-Builder within the period specified in the contract clauses. Otherwise, Design-Builder gets the objection right.

Risk 8 - Difficulties/delays in availability of materials, equipment and labor: Design-Builder is absolutely liable for difficulties/delays in availability of materials, equipment and labor. This is because Design-Builder possesses the controlling power of the construction site and material purchases. Nevertheless, if Design-Builder faces with any unsolvable situations associated with this risk, he can demand time extension or cost compensation from Owner's Representative (Clause 8.3).

Risk 9 - Inadequate quality of work and need for correction: According to the relevant contract clauses, Design-Builder is responsible for correcting the work items of which inadequate quality is observed by Owner's Representative; however, if they are caused due to the following reasons (Clauses 15, 12.2 & 12.4):

- Due to design
- Due to incompliance of the materials and the working techniques with the contract specifications.
- Due to disobedience of design-builder to his other liabilities.

Risk 10 - Changes in quantity/scope of work: In case of a change in quantity or scope of work, Design-Builder makes necessary modifications on project cost and schedule, and delivers it to Owner's Representative for appointment. Next, Owner's Representative answers Design-builder as soon as possible. Design-builder cannot start to perform the offered changes before the Owner's approval. The content of the Owner's answer determines the allocation basis of this risk. (Clause 14)

Risk 11 – Inflation: Inflation can be defined as "a general increase in the prices of goods and services in a country" [73]. It is an essential risk for the construction projects. Unfortunately, Clause 13.1 allocates the inflation risk to the Design-Builder. This situation further increases the Design-Builder's cost risk. The important parts of the Clause 13.1 are as follows:

- The payments are made with respect to the fixed-price.
- No arrangement can be made in the contract price because of the probable changes in material, labor and likely costs.

Risk 12 – Weather conditions: Clause 17.3 emphasizes that the effects of natural events for which it is not expected from any experienced contractor to take precautions belong to the Owner's risks. The delays caused due to the extreme weather conditions can be considered and evaluated within the scope of this clause. However, weather risk generally belongs to Design-Builder in practice because the risk of weather is not among the unforeseeable risks any more due to the advancements in meteorological estimating. In other words, Design-Builder is expected to consider the weather risk in detail in schedule planning.

Risk 13 – Accidents: The accident risk is completely allocated to Design-Builder and it is desired from him to transfer this risk by means of insurance according to the Clause 18.3 and 18.4. Design-Builder is fully liable to undertake all the insurance payments.

Risk 14 – Social events: This subject is clarified in Clause 17.3. The risks associated with unexpected social events like war or rebellious actions are absolutely allocated to Owner.

APPENDIX C

CASE STUDY I – TABLES AND FIGURES OF RISK ANALYSIS

Table C.1 Time schedule risk analysis spreadsheet model of 200 m2 office

Time Schedule Risk Analysis													
Activity Number	Activity Name	Predecessor	Minimum Duration (days)	Likely Duration (days)	Maximum Duration (days)	Simulated Duration (days)	Early Start Time	Early Finish Time	Late Start Time	Late Finish Time	Total Float (days)	0=critical activity 1=non-critical activity
1	Start		0	0	0	0,0	0,0	0,0	0,0	0,0	0,0	0
2	Site delivery	1 FS	1	3	6	3,6	0,0	3,6	0,0	3,6	0,0	0
3	Procure construction materials, equipment and furniture	1 FS	8	10	15	11,7	0,0	11,7	0,1	11,8	0,1	1
4	Remove existing materials	2 FS	2	3	5	3,8	3,6	7,4	3,6	7,4	0,0	0
5	Detail measurement; by aluminum subcontractor	4 FS	1	2	3	2,1	7,4	9,5	7,4	9,5	0,0	0
6	Detail measurement; by glazier subcontractor	4 FS	1	2	3	2,1	7,4	9,5	20,2	22,3	12,8	1
7	Detail measurement; by ATM cabin subcontractor	4 FS	1	2	3	2,1	7,4	9,5	26,2	28,3	18,8	1
8	Detail measurement; by advertisement panel subcontractor	4 FS	1	2	3	2,1	7,4	9,5	28,8	30,9	21,4	1
9	Detail measurement; by safe room subcontractor	4 FS	1	2	3	2,1	7,4	9,5	23,0	25,1	15,6	1
10	Install electrical and automation fitting	3;4 FS	2	3	4	3,1	11,7	14,8	13,4	16,5	1,7	1
11	Install HVAC, sanitary and mechanical fitting	3;4 FS	3	4	6	4,7	11,7	16,4	11,8	16,5	0,1	1
12	Install suspended ceiling	3;10;11 FS	2	3	5	3,7	16,4	20,1	16,5	20,2	0,1	1
13	Cover mechanical and electrical units	3;10;11 FS	2	3	4	3,1	16,4	19,5	17,0	20,2	0,6	1
14	Level slab sub-layer (all the floors)	12;13 FS	1	2	3	2,2	20,1	22,2	20,2	22,3	0,1	1
15	Cover slab (all the floors)	14;3 FS	1	3	4	2,8	22,2	25,0	22,3	25,1	0,1	1
16	Paint interior walls and columns	15 FS	2	3	5	3,8	25,0	28,8	29,3	33,1	4,3	1
17	Paint base floor ceiling	15 FS	1	2	3	2,2	25,0	27,2	30,9	33,1	5,9	1
18	Finish WC and kitchen works	3;10;11 FS	2	3	4	3,1	16,4	19,5	29,9	33,1	13,5	1
19	Install aluminum joineries	5FS+10d	1	3	4	2,8	19,5	22,3	19,5	22,3	0,0	0
20	Install inner and outer joinery glasses	19;6 FS	1	2	3	2,2	22,3	24,5	22,3	24,5	0,0	0
21	Install security alarm system	20 FS	1	2	3	2,2	24,5	26,7	30,9	33,1	6,4	1
22	Construct ATM cabin and install money machine	19;7 FS	3	4	6	4,8	22,3	27,0	28,3	33,1	6,0	1
23	Construct safe room and install safe box	15;9 FS	5	7	10	8,0	25,0	33,0	25,1	33,1	0,1	1
24	Finish exterior works	19;3 FS	1	2	3	2,2	22,3	24,5	28,7	30,9	6,5	1
25	Install advertisement panel	24;8 FS	1	2	3	2,2	24,5	26,6	30,9	33,1	6,5	1
26	Install furniture	20;3 FS	1	2	3	2,1	24,5	26,6	24,5	26,6	0,0	0
27	Finish interior works	26 FS	1	2	3	2,2	26,6	28,8	26,6	28,8	0,0	0
28	Install communication and automation systems	27 FS	1	2	3	2,2	28,8	30,9	28,8	30,9	0,0	0
29	Check all the works and test all the systems	28 FS	1	2	3	2,2	30,9	33,1	30,9	33,1	0,0	0
30	Finish	22;23;25;29;18;16;17;21 FS	0	0	0	0,0	33,1	33,1	33,1	33,1	0,0	0

Table C.2 Time schedule risk analysis spreadsheet model of 300 m2 office

Time Schedule Risk Analysis													
Activity Number	Activity Name	Predecessor	Minimum Duration (days)	Likely Duration (days)	Maximum Duration (days)	Simulated Duration (days)	Early Start Time	Early Finish Time	Late Start Time	Late Finish Time	Total Float (days)	0=critical activity 1=non-critical activity
1	Start		0	0	0	0,0	0,0	0,0	0,0	0,0	0,0	0
2	Site delivery	1 FS	1	3	6	3,6	0,0	3,6	0,0	3,6	0,0	0
3	Procure construction materials, equipment and furniture	1 FS	8	12	15	11,7	0,0	11,7	0,1	11,8	0,1	1
4	Remove existing materials	2 FS	2	4	6	4,3	3,6	8,0	3,6	8,0	0,0	0
5	Detail measurement; by aluminum subcontractor	4 FS	1	2	3	2,1	8,0	10,1	8,0	10,1	0,0	0
6	Detail measurement; by glazier subcontractor	4 FS	1	2	3	2,1	8,0	10,1	21,2	23,3	13,2	1
7	Detail measurement; by ATM cabin subcontractor	4 FS	1	2	3	2,1	8,0	10,1	27,2	29,3	19,2	1
8	Detail measurement; by advertisement panel subcontractor	4 FS	1	2	3	2,1	8,0	10,1	29,8	31,9	21,8	1
9	Detail measurement; by safe room subcontractor	4 FS	1	2	3	2,1	8,0	10,1	24,0	26,1	16,0	1
10	Install electrical and automation fitting	3;4 FS	2	3	5	3,7	11,7	15,4	13,4	17,0	1,7	1
11	Install HVAC, sanitary and mechanical fitting	3;4 FS	3	5	7	5,2	11,7	16,9	11,8	17,0	0,1	1
12	Install suspended ceiling	3;10;11 FS	2	4	5	3,7	16,9	20,6	17,1	20,7	0,1	1
13	Cover mechanical and electrical units	3;10;11 FS	2	3	5	3,7	16,9	20,6	17,0	20,7	0,1	1
14	Level slab sub-layer (all the floors)	12;13 FS	1	2	3	2,2	20,6	22,8	20,7	22,9	0,1	1
15	Cover slab (all the floors)	14;3 FS	2	3	4	3,2	22,8	26,0	22,9	26,1	0,1	1
16	Paint interior walls and columns	15 FS	2	4	5	3,8	26,0	29,8	30,3	34,1	4,3	1
17	Paint base floor ceiling	15 FS	1	2	3	2,2	26,0	28,2	31,9	34,1	5,9	1
18	Finish WC and kitchen works	3;10;11 FS	2	3	4	3,1	16,9	20,1	30,9	34,1	14,0	1
19	Install aluminum joineries	5FS+10d	2	3	4	3,2	20,1	23,3	20,1	23,3	0,0	0
20	Install inner and outer joinery glasses	19;6 FS	1	2	3	2,2	23,3	25,5	23,3	25,5	0,0	0
21	Install security alarm system	20 FS	1	2	3	2,2	25,5	27,6	31,9	34,1	6,4	1
22	Construct ATM cabin and install money machine	19;7 FS	3	4	6	4,8	23,3	28,0	29,3	34,1	6,0	1
23	Construct safe room and install safe box	15;9 FS	5	7	10	8,0	26,0	34,0	26,1	34,1	0,1	1
24	Finish exterior works	19;3 FS	1	2	3	2,2	23,3	25,4	29,7	31,9	6,5	1
25	Install advertisement panel	24;8 FS	1	2	3	2,2	25,4	27,6	31,9	34,1	6,5	1
26	Install furniture	20;3 FS	1	2	3	2,1	25,5	27,6	25,5	27,6	0,0	0
27	Finish interior works	26 FS	1	2	3	2,2	27,6	29,7	27,6	29,7	0,0	0
28	Install communication and automation systems	27 FS	1	2	3	2,2	29,7	31,9	29,7	31,9	0,0	0
29	Check all the works and test all the systems	28 FS	1	2	3	2,2	31,9	34,1	31,9	34,1	0,0	0
30	Finish	22;23;25;29;18;16;17;21 FS	0	0	0	0,0	34,1	34,1	34,1	34,1	0,0	0

Table C.3 Time schedule risk analysis spreadsheet model of 400 m2 office

Time Schedule Risk Analysis													
Activity Number	Activity Name	Predecessor	Minimum Duration (days)	Likely Duration (days)	Maximum Duration (days)	Simulated Duration (days)	Early Start Time	Early Finish Time	Late Start Time	Late Finish Time	Total Float (days)	0=critical activity 1=non-critical activity
1	Start		0	0	0	0,0	0,0	0,0	0,0	0,0	0,0	0
2	Site delivery	1 FS	1	3	6	3,6	0,0	3,6	3,1	6,8	3,1	1
3	Procure construction materials, equipment and furniture	1 FS	8	12	20	14,4	0,0	14,4	0,0	14,4	0,0	0
4	Remove existing materials	2 FS	2	5	7	4,9	3,6	8,6	6,8	11,7	3,1	1
5	Detail measurement; by aluminum subcontractor	4 FS	1	2	4	2,7	8,6	11,2	11,7	14,3	3,1	1
6	Detail measurement; by glazier subcontractor	4 FS	1	2	4	2,7	8,6	11,2	24,9	27,5	16,3	1
7	Detail measurement; by ATM cabin subcontractor	4 FS	1	2	4	2,7	8,6	11,2	30,9	33,6	22,3	1
8	Detail measurement; by advertisement panel subcontractor	4 FS	1	2	4	2,7	8,6	11,2	33,5	36,2	24,9	1
9	Detail measurement; by safe room subcontractor	4 FS	1	2	4	2,7	8,6	11,2	27,7	30,4	19,2	1
10	Install electrical and automation fitting	3;4 FS	2	4	6	4,2	14,4	18,6	15,9	20,2	1,6	1
11	Install HVAC, sanitary and mechanical fitting	3;4 FS	3	5	8	5,8	14,4	20,2	14,4	20,2	0,0	0
12	Install suspended ceiling	3;10;11 FS	2	5	6	4,2	20,2	24,4	20,2	24,4	0,0	1
13	Cover mechanical and electrical units	3;10;11 FS	2	4	6	4,3	20,2	24,4	20,2	24,4	0,0	0
14	Level slab sub-layer (all the floors)	12;13 FS	1	3	4	2,8	24,4	27,2	24,4	27,2	0,0	0
15	Cover slab (all the floors)	14;3 FS	2	3	4	3,2	27,2	30,4	27,2	30,4	0,0	0
16	Paint interior walls and columns	15 FS	2	4	5	3,8	30,4	34,1	34,6	38,3	4,2	1
17	Paint base floor ceiling	15 FS	1	2	3	2,2	30,4	32,5	36,1	38,3	5,8	1
18	Finish WC and kitchen works	3;10;11 FS	2	3	4	3,1	20,2	23,3	35,2	38,3	15,0	1
19	Install aluminum joineries	5FS+10d	2	3	4	3,2	21,2	24,4	24,3	27,5	3,1	1
20	Install inner and outer joinery glasses	19;6 FS	1	2	3	2,2	24,4	26,6	27,5	29,7	3,1	1
21	Install security alarm system	20 FS	1	2	3	2,2	26,6	28,8	36,1	38,3	9,5	1
22	Construct ATM cabin and install money machine	19;7 FS	3	4	6	4,8	24,4	29,2	33,6	38,3	9,1	1
23	Construct safe room and install safe box	15;9 FS	5	7	10	8,0	30,4	38,3	30,4	38,3	0,0	0
24	Finish exterior works	19;3 FS	1	2	4	2,8	24,4	27,2	33,4	36,2	9,0	1
25	Install advertisement panel	24;8 FS	1	2	3	2,2	27,2	29,3	36,2	38,3	9,0	1
26	Install furniture	20;3 FS	1	2	3	2,1	26,6	28,7	29,7	31,8	3,1	1
27	Finish interior works	26 FS	1	2	3	2,2	28,7	30,9	31,8	34,0	3,1	1
28	Install communication and automation systems	27 FS	1	2	3	2,2	30,9	33,0	34,0	36,2	3,1	1
29	Check all the works and test all the systems	28 FS	1	2	3	2,2	33,0	35,2	36,2	38,3	3,1	1
30	Finish	22;23;25;29;18;16;17;21 FS	0	0	0	0,0	38,3	38,3	38,3	38,3	0,0	0

Table C.4 Time schedule risk analysis spreadsheet model of 500 m2 office

Time Schedule Risk Analysis														
Activity Number	Activity Name	Predecessor	Minimum Duration (days)	Likely Duration (days)	Maximum Duration (days)	Simulated Duration (days)	Early Start Time	Early Finish Time	Late Start Time	Late Finish Time	Total Float (days)	0=critical activity 1=non-critical activity
1	Start		0	0	0	0,0	0,0	0,0	0,0	0,0	0,0	0
2	Site delivery	1 FS	1	3	6	3,6	0,0	3,6	8,4	12,1	8,4	1
3	Procure construction materials, equipment and furniture	1 FS	10	15	25	18,0	0,0	18,0	0,0	18,0	0,0	0
4	Remove existing materials	2 FS	3	6	8	5,9	3,6	9,6	12,1	18,0	8,4	1
5	Detail measurement; by aluminum subcontractor	4 FS	1	3	4	2,7	9,6	12,2	18,2	20,9	8,7	1
6	Detail measurement; by glazier subcontractor	4 FS	1	3	4	2,7	9,6	12,2	32,0	34,7	22,5	1
7	Detail measurement; by ATM cabin subcontractor	4 FS	1	3	4	2,7	9,6	12,2	38,6	41,3	29,1	1
8	Detail measurement; by advertisement panel subcontractor	4 FS	1	3	4	2,7	9,6	12,2	41,2	43,9	31,7	1
9	Detail measurement; by safe room subcontractor	4 FS	1	3	4	2,7	9,6	12,2	35,4	38,1	25,9	1
10	Install electrical and automation fitting	3;4 FS	3	5	8	5,8	18,0	23,8	19,0	24,8	1,0	1
11	Install HVAC, sanitary and mechanical fitting	3;4 FS	4	6	9	6,8	18,0	24,8	18,0	24,8	0,0	0
12	Install suspended ceiling	3;10;11 FS	3	6	8	5,8	24,8	30,6	24,8	30,6	0,0	0
13	Cover mechanical and electrical units	3;10;11 FS	3	5	7	5,3	24,8	30,0	25,3	30,6	0,5	1
14	Level slab sub-layer (all the floors)	12;13 FS	2	3	5	3,8	30,6	34,3	30,6	34,3	0,0	0
15	Cover slab (all the floors)	14;3 FS	2	3	5	3,8	34,3	38,1	34,3	38,1	0,0	0
16	Paint interior walls and columns	15 FS	3	4	6	4,8	38,1	42,9	41,3	46,0	3,2	1
17	Paint base floor ceiling	15 FS	1	2	3	2,2	38,1	40,3	43,9	46,0	5,8	1
18	Finish WC and kitchen works	3;10;11 FS	3	4	5	4,1	24,8	28,9	41,9	46,0	17,1	1
19	Install aluminum joineries	5FS+10d	2	3	5	3,8	22,2	26,0	30,9	34,7	8,7	1
20	Install inner and outer joinery glasses	19;6 FS	1	2	3	2,2	26,0	28,2	34,7	36,9	8,7	1
21	Install security alarm system	20 FS	1	2	3	2,2	28,2	30,4	43,8	46,0	15,7	1
22	Construct ATM cabin and install money machine	19;7 FS	3	4	6	4,8	26,0	30,8	41,3	46,0	15,3	1
23	Construct safe room and install safe box	15;9 FS	5	7	10	8,0	38,1	46,0	38,1	46,0	0,0	0
24	Finish exterior works	19;3 FS	2	3	5	3,8	26,0	29,8	40,1	43,9	14,1	1
25	Install advertisement panel	24;8 FS	1	2	3	2,2	29,8	31,9	43,9	46,0	14,1	1
26	Install furniture	20;3 FS	1	2	4	2,7	28,2	30,9	36,9	39,6	8,7	1
27	Finish interior works	26 FS	1	2	3	2,2	30,9	33,0	39,6	41,7	8,7	1
28	Install communication and automation systems	27 FS	1	2	3	2,2	33,0	35,2	41,7	43,9	8,7	1
29	Check all the works and test all the systems	28 FS	1	2	3	2,2	35,2	37,3	43,9	46,0	8,7	1
30	Finish	22;23;25;29;18;16;17;21 FS	0	0	0	0,0	46,0	46,0	46,0	46,0	0,0	0

Table C.5 Time schedule risk analysis spreadsheet model of 600 m2 office

Time Schedule Risk Analysis													
Activity Number	Activity Name	Predecessor	Minimum Duration (days)	Likely Duration (days)	Maximum Duration (days)	Simulated Duration (days)	Early Start Time	Early Finish Time	Late Start Time	Late Finish Time	Total Float (days)	0=critical activity 1=non-critical activity
1	Start		0	0	0	0,0	0,0	0,0	0,0	0,0	0,0	0
2	Site delivery	1 FS	1	3	6	3,6	0,0	3,6	6,8	10,5	6,8	1
3	Procure construction materials, equipment and furniture	1 FS	10	15	25	18,0	0,0	18,0	0,0	18,0	0,0	0
4	Remove existing materials	2 FS	4	6	10	7,5	3,6	11,1	10,5	18,0	6,8	1
5	Detail measurement; by aluminum subcontractor	4 FS	1	3	4	2,7	11,1	13,8	18,2	20,9	7,1	1
6	Detail measurement; by glazier subcontractor	4 FS	1	3	4	2,7	11,1	13,8	32,0	34,7	20,9	1
7	Detail measurement; by ATM cabin subcontractor	4 FS	1	3	4	2,7	11,1	13,8	38,6	41,3	27,5	1
8	Detail measurement; by advertisement panel subcontractor	4 FS	1	3	4	2,7	11,1	13,8	41,2	43,9	30,1	1
9	Detail measurement; by safe room subcontractor	4 FS	1	3	4	2,7	11,1	13,8	35,4	38,1	24,3	1
10	Install electrical and automation fitting	3;4 FS	4	6	8	6,2	18,0	24,2	18,5	24,8	0,6	1
11	Install HVAC, sanitary and mechanical fitting	3;4 FS	4	7	9	6,8	18,0	24,8	18,0	24,8	0,0	0
12	Install suspended ceiling	3;10;11 FS	3	6	8	5,8	24,8	30,6	24,8	30,6	0,0	0
13	Cover mechanical and electrical units	3;10;11 FS	3	5	7	5,3	24,8	30,0	25,3	30,6	0,5	1
14	Level slab sub-layer (all the floors)	12;13 FS	2	4	5	3,8	30,6	34,3	30,6	34,3	0,0	0
15	Cover slab (all the floors)	14;3 FS	2	4	5	3,8	34,3	38,1	34,3	38,1	0,0	0
16	Paint interior walls and columns	15 FS	3	5	6	4,8	38,1	42,9	41,3	46,0	3,2	1
17	Paint base floor ceiling	15 FS	1	2	3	2,2	38,1	40,3	43,9	46,0	5,8	1
18	Finish WC and kitchen works	3;10;11 FS	3	4	5	4,1	24,8	28,9	41,9	46,0	17,1	1
19	Install aluminum joineries	5FS+10d	2	3	5	3,8	23,8	27,6	30,9	34,7	7,1	1
20	Install inner and outer joinery glasses	19;6 FS	1	2	3	2,2	27,6	29,8	34,7	36,9	7,1	1
21	Install security alarm system	20 FS	1	2	3	2,2	29,8	32,0	43,8	46,0	14,1	1
22	Construct ATM cabin and install money machine	19;7 FS	3	4	6	4,8	27,6	32,3	41,3	46,0	13,7	1
23	Construct safe room and install safe box	15;9 FS	5	7	10	8,0	38,1	46,0	38,1	46,0	0,0	0
24	Finish exterior works	19;3 FS	2	3	5	3,8	27,6	31,3	40,1	43,9	12,5	1
25	Install advertisement panel	24;8 FS	1	2	3	2,2	31,3	33,5	43,9	46,0	12,5	1
26	Install furniture	20;3 FS	1	2	4	2,7	29,8	32,5	36,9	39,6	7,1	1
27	Finish interior works	26 FS	1	2	3	2,2	32,5	34,6	39,6	41,7	7,1	1
28	Install communication and automation systems	27 FS	1	2	3	2,2	34,6	36,8	41,7	43,9	7,1	1
29	Check all the works and test all the systems	28 FS	1	2	3	2,2	36,8	38,9	43,9	46,0	7,1	1
30	Finish	22;23;25;29;18;16;17;21 FS	0	0	0	0,0	46,0	46,0	46,0	46,0	0,0	0

Table C.6 Time schedule risk analysis spreadsheet model of 1000 m2 office

Time Schedule Risk Analysis													
Activity Number	Activity Name	Predecessor	Minimum Duration (days)	Likely Duration (days)	Maximum Duration (days)	Simulated Duration (days)	Early Start Time	Early Finish Time	Late Start Time	Late Finish Time	Total Float (days)	0=critical activity 1=non-critical activity
1	Start		0	0	0	0,0	0,0	0,0	0,0	0,0	0,0	0
2	Site delivery	1 FS	1	3	6	3,6	0,0	3,6	7,5	11,1	7,5	1
3	Procure construction materials, equipment and furniture	1 FS	10	18	30	20,6	0,0	20,6	0,0	20,6	0,0	0
4	Remove existing materials	2 FS	6	9	12	9,5	3,6	13,1	11,1	20,6	7,5	1
5	Detail measurement; by aluminum subcontractor	4 FS	2	3	5	3,7	13,1	16,8	24,9	28,6	11,8	1
6	Detail measurement; by glazier subcontractor	4 FS	2	3	5	3,7	13,1	16,8	39,1	42,8	26,0	1
7	Detail measurement; by ATM cabin subcontractor	4 FS	1	3	4	2,7	13,1	15,8	49,7	52,3	36,5	1
8	Detail measurement; by advertisement panel subcontractor	4 FS	1	3	4	2,7	13,1	15,8	52,3	55,0	39,2	1
9	Detail measurement; by safe room subcontractor	4 FS	1	3	4	2,7	13,1	15,8	46,1	48,7	32,9	1
10	Install electrical and automation fitting	3;4 FS	6	8	10	8,2	20,6	28,9	21,2	29,4	0,6	1
11	Install HVAC, sanitary and mechanical fitting	3;4 FS	6	9	11	8,8	20,6	29,4	20,6	29,4	0,0	0
12	Install suspended ceiling	3;10;11 FS	5	8	10	7,8	29,4	37,2	29,4	37,2	0,0	0
13	Cover mechanical and electrical units	3;10;11 FS	4	6	7	5,7	29,4	35,1	31,5	37,2	2,1	1
14	Level slab sub-layer (all the floors)	12;13 FS	4	5	7	5,8	37,2	43,0	37,2	43,0	0,0	0
15	Cover slab (all the floors)	14;3 FS	4	5	7	5,8	43,0	48,7	43,0	48,7	0,0	0
16	Paint interior walls and columns	15 FS	5	7	9	7,4	48,7	56,1	49,8	57,1	1,0	1
17	Paint base floor ceiling	15 FS	2	3	4	3,2	48,7	51,9	53,9	57,1	5,2	1
18	Finish WC and kitchen works	3;10;11 FS	3	4	5	4,1	29,4	33,6	53,0	57,1	23,6	1
19	Install aluminum joineries	5FS+10d	3	4	5	4,2	26,8	31,0	38,6	42,8	11,8	1
20	Install inner and outer joinery glasses	19;6 FS	2	3	4	3,2	31,0	34,2	42,8	45,9	11,8	1
21	Install security alarm system	20 FS	1	2	3	2,2	34,2	36,4	54,9	57,1	20,7	1
22	Construct ATM cabin and install money machine	19;7 FS	3	4	6	4,8	31,0	35,8	52,3	57,1	21,4	1
23	Construct safe room and install safe box	15;9 FS	6	8	10	8,4	48,7	57,1	48,7	57,1	0,0	0
24	Finish exterior works	19;3 FS	4	5	7	5,8	31,0	36,8	49,2	55,0	18,2	1
25	Install advertisement panel	24;8 FS	1	2	3	2,2	36,8	38,9	55,0	57,1	18,2	1
26	Install furniture	20;3 FS	2	4	5	3,7	34,2	37,9	45,9	49,6	11,8	1
27	Finish interior works	26 FS	2	3	4	3,2	37,9	41,0	49,6	52,8	11,8	1
28	Install communication and automation systems	27 FS	1	2	3	2,2	41,0	43,2	52,8	55,0	11,8	1
29	Check all the works and test all the systems	28 FS	1	2	3	2,2	43,2	45,3	55,0	57,1	11,8	1
30	Finish	22;23;25;29;18;16;17;21 FS	0	0	0	0,0	57,1	57,1	57,1	57,1	0,0	0

Table C.7 Probablity distributions assigned to the risks

	1	2	3	4	5	6	7	8	9	10	11	12
Risks:	Defective design	Design changes	Delay in design	Subcontractors' default	Fluctuation in labor productivity	Delay in resolving disputes	Owner delays	Difficulties/delays in availability of materials	Inadequate quality of work and need for correction	Changes in quantity/scope of work	Weather conditions	Accidents
Distribution Type:	Triangle	Triangle	Triangle	Normal	Triangle	Normal	Triangle	Triangle	Triangle	Triangle	Triangle	Uniform
Mean:	0,45	0,43	0,50	0,40	0,42	0,30	0,47	0,42	0,40	0,48	0,56	0,50

Table C.8 Correlation coefficients assigned to the risks

Risks:	1 Defective design	2 Design changes	3 Delay in design	4 Subcontractors' default	5 Fluctuation in labor productivity	6 Delay in resolving disputes	7 Owner delays (unable to get approvals, lack of payment, etc.)	8 Difficulties/delays in availability of materials, equipment and labor	9 Inadequate quality of work and need for correction	10 Changes in quantity/scope of work	11 Weather conditions	12 Accidents
1	1,00											
2	0,76	1,00										
3	0,21	0,39	1,00									
4	0,29	0,42	0,10	1,00								
5	0,00	0,00	0,00	0,10	1,00							
6	0,31	0,49	0,20	0,60	0,00	1,00						
7	0,20	0,40	0,10	0,00	0,00	0,40	1,00					
8	-0,01	0,01	0,00	0,00	0,00	0,00	0,00	1,00				
9	0,10	0,00	0,00	0,30	0,20	0,30	0,00	0,00	1,00			
10	0,03	0,56	0,01	0,59	0,00	0,31	0,20	0,19	0,00	1,00		
11	0,00	-0,01	0,00	0,00	0,00	0,00	0,00	0,60	0,00	0,00	1,00	
12	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,30	1,00

Table C.9 Design and construction durations of offices used in deterministic network planning

Net Floor Area (m2)	*Design Duration (days)*	*Construction Duration (days)*
200 m2	4,0	35,0
300 m2	6,0	36,0
400 m2	8,0	41,0
500 m2	10,0	49,0
600 m2	12,0	49,0
1000 m2	20,0	60,0

Table C.10 Table of central offices' schedule plan

Task Name	*Duration (days)*	*Start*	*Finish*	*Predecessors*	*Resource Names*
Start	0	01.05.03	01.05.03		
Diyarbakır/central/design	20	10.05.03	02.06.03	1	Design Group
Bağlar/Diyarbakır/central/design	6	01.05.03	07.05.03	1	Design Group
Ofis/Diyarbakır/central/design	8	01.05.03	09.05.03	1	Design Group
Yenişehir/Diyarbakır/central/design	4	08.05.03	12.05.03	3	Design Group
University/Diyarbakır/central/design	4	24.05.03	28.05.03	4	Design Group
Şanlıurfa/central/design	20	03.06.03	25.06.03	2	Design Group
Haşimiye/Şanlıurfa/central/design	10	13.05.03	23.05.03	5	Design Group
Gaziantep/central/design	20	26.06.03	18.07.03	8	Design Group
Akyol/Gaziantep/central/design	12	29.05.03	11.06.03	6	Design Group
Karşıyaka/Gaziantep/central/design	12	12.06.03	25.06.03	10	Design Group
Şırahanı/Gaziantep/central/design	10	19.07.03	30.07.03	9	Design Group
Suburcu/Gaziantep/central/design	6	01.07.03	07.07.03	14	Design Group
University/Gaziantep/central/design	4	26.06.03	30.06.03	11	Design Group
Batman/central/design	20	22.07.03	13.08.03	7	Design Group
Siirt/central/design	20	31.07.03	22.08.03	12	Design Group
Kilis/central/design	12	08.07.03	21.07.03	13	Design Group
Şırnak/central/design	8	23.08.03	01.09.03	15	Design Group
Mardin/central/design	12	14.08.03	27.08.03	17	Design Group
Diyarbakır/central/construction	60	09.06.03	16.08.03	2FS+5d	Construction Group
Bağlar/Diyarbakır/central/construction	36	14.05.03	24.06.03	3FS+5d	Construction Group
Ofis/Diyarbakır/central/construction	41	16.05.03	02.07.03	4FS+5d	Construction Group
Yenişehir/Diyarbakır/central/construction	35	19.05.03	27.06.03	5FS+5d	Construction Group
University/Diyarbakır/central/construction	35	28.06.03	07.08.03	23;6FS+5d	Construction Group

Table C.10 (cont'd)

Task Name	*Duration (days)*	*Start*	*Finish*	*Predecessors*	*Resource Names*
Şanlıurfa/central/construction	60	02.07.03	09.09.03	21;7FS+5d	Construction Group
Haşimiye/Şanlıurfa/central/construction	49	03.07.03	28.08.03	22;8FS+5d	Construction Group
Gaziantep/central/construction	60	18.08.03	25.10.03	20;9FS+5d	Construction Group
Akyol/Gaziantep/central/construction	49	08.08.03	03.10.03	24;10FS+5d	Construction Group
Karşıyaka/Gaziantep/central/construction	49	29.08.03	24.10.03	26;11FS+5d	Construction Group
Şırahanı/Gaziantep/central/construction	49	10.09.03	05.11.03	25;12FS+5d	Construction Group
Suburcu/Gaziantep/central/construction	36	27.10.03	06.12.03	27;13FS+5d	Construction Group
University/Gaziantep/central/construction	35	04.10.03	13.11.03	28;14FS+5d	Construction Group
Batman/central/construction	60	06.11.03	14.01.04	30;15FS+5d	Construction Group
Siirt/central/construction	60	14.11.03	22.01.04	32;16FS+5d	Construction Group
Kilis/central/construction	49	25.10.03	20.12.03	29;17FS+5d	Construction Group
Şırnak/central/construction	41	08.12.03	23.01.04	31;18FS+5d	Construction Group
Mardin/central/construction	49	22.12.03	16.02.04	35;19FS+5d	Construction Group
Finish	0	16.02.04	16.02.04	33;34;36;37	

Table C.11 Table of town offices' schedule plan

Task Type	*Task Name*	*Duration (days)*	*Start*	*Finish*	*Predecessors*	*Resource Names*
	Start	0	03.09.03	03.09.03		
Design	Bismil	12	03.09.03	16.09.03	1	Design Group
	Çermik	8	03.09.03	11.09.03	1	Design Group
	Çınar	6	17.09.03	23.09.03	2	Design Group
	Çüngüş	6	12.09.03	18.09.03	3	Design Group
	Dicle	6	24.09.03	30.09.03	4	Design Group
	Eğil	4	19.09.03	23.09.03	5	Design Group
	Ergani	6	24.09.03	30.09.03	7	Design Group
	Hani	6	01.10.03	07.10.03	6	Design Group
	Hazro	6	08.10.03	14.10.03	9	Design Group
	Kulp	4	15.10.03	18.10.03	10	Design Group
	Lice	4	20.10.03	23.10.03	11	Design Group
	Silvan	8	01.10.03	09.10.03	8	Design Group
	Akçakale	4	10.10.03	14.10.03	13	Design Group
	Birecik	6	15.10.03	21.10.03	14	Design Group
	Bozova	6	22.10.03	28.10.03	15	Design Group
	Ceylanpınar	8	24.10.03	01.11.03	12	Design Group
	Halfeti	8	29.10.03	06.11.03	16	Design Group
	Harran	6	07.11.03	13.11.03	18	Design Group
	Hilvan	4	03.11.03	06.11.03	17	Design Group
	Siverek	8	07.11.03	15.11.03	20	Design Group
	Suruç	6	14.11.03	20.11.03	19	Design Group
	Viranşehir	6	17.11.03	22.11.03	21	Design Group
	Araban	4	24.11.03	27.11.03	23	Design Group

Table C.11 (cont'd)

Task Type	*Task Name*	*Duration (days)*	*Start*	*Finish*	*Predecessors*	*Resource Names*
Design	Islahiye	6	28.11.03	04.12.03	24	Design Group
	Karkamış	6	05.12.03	11.12.03	25	Design Group
	Nizip	10	21.11.03	02.12.03	22	Design Group
	Nurdağı	4	03.12.03	06.12.03	27	Design Group
	Oğuzeli	6	08.12.03	13.12.03	28	Design Group
	Yavuzeli	6	12.12.03	18.12.03	26	Design Group
	Beşiri	8	15.12.03	23.12.03	29	Design Group
	Gercüş	4	24.12.03	27.12.03	31	Design Group
	Kozluk	12	29.12.03	10.01.04	32	Design Group
	Sason	10	19.12.03	30.12.03	30	Design Group
	Baykan	4	31.12.03	03.01.04	34	Design Group
	Eruh	8	05.01.04	13.01.04	35	Design Group
	Kurtalan	8	14.01.04	22.01.04	36	Design Group
	Pervari	8	12.01.04	20.01.04	33	Design Group
	Şirvan	6	23.01.04	29.01.04	37	Design Group
	Musabeyli	6	21.01.04	27.01.04	38	Design Group
	Beytüşşebap	6	30.01.04	05.02.04	39	Design Group
	Cizre	10	06.02.04	17.02.04	41	Design Group
	İdil	4	18.02.04	21.02.04	42	Design Group
	Silopi	12	28.01.04	10.02.04	40	Design Group
	Uludere	6	11.02.04	17.02.04	44	Design Group
	Derik	6	18.02.04	24.02.04	45	Design Group
	Kızıltepe	10	23.02.04	04.03.04	43	Design Group
	Midyat	8	05.03.04	13.03.04	47	Design Group
	Midyatkesimi	6	15.03.04	20.03.04	48	Design Group

Table C.11 (cont'd)

Task Type	*Task Name*	*Duration (days)*	*Start*	*Finish*	*Predecessors*	*Resource Names*
Design	Nusaybin	8	25.02.04	04.03.04	46	Design Group
	Ömerli	12	05.03.04	18.03.04	50	Design Group
	Savur	6	19.03.04	25.03.04	51	Design Group
	Yeşilli	6	22.03.04	27.03.04	49	Design Group
Construction	Bismil	49	24.01.04	20.03.04	2FS+5d;1FS+123d	Construction Group
	Çermik	41	22.03.04	07.05.04	3FS+5d;54	Construction Group
	Çınar	36	08.05.04	18.06.04	4FS+5d;55	Construction Group
	Çüngüş	36	19.06.04	30.07.04	5FS+5d;56	Construction Group
	Dicle	36	31.07.04	10.09.04	6FS+5d;57	Construction Group
	Eğil	35	11.09.04	21.10.04	7FS+5d;58	Construction Group
	Ergani	36	22.10.04	02.12.04	8FS+5d;59	Construction Group
	Hani	36	03.12.04	13.01.05	9FS+5d;60	Construction Group
	Hazro	36	14.01.05	24.02.05	10FS+5d;61	Construction Group
	Kulp	35	25.02.05	06.04.05	11FS+5d;62	Construction Group
	Lice	35	07.04.05	17.05.05	12FS+5d;63	Construction Group
	Silvan	41	18.05.05	04.07.05	13FS+5d;64	Construction Group
	Akçakale	35	15.01.04	24.02.04	14FS+5d;1FS+115d	Construction Group
	Birecik	36	25.02.04	06.04.04	15FS+5d;66	Construction Group
	Bozova	36	07.04.04	18.05.04	16FS+5d;67	Construction Group
	Ceylanpınar	41	19.05.04	05.07.04	17FS+5d;68	Construction Group
	Halfeti	41	06.07.04	21.08.04	18FS+5d;69	Construction Group
	Harran	36	23.08.04	02.10.04	19FS+5d;70	Construction Group
	Hilvan	35	04.10.04	12.11.04	20FS+5d;71	Construction Group
	Siverek	41	13.11.04	30.12.04	21FS+5d;72	Construction Group
	Suruç	36	31.12.04	10.02.05	22FS+5d;73	Construction Group

Table C.11 (cont'd)

Task Type	*Task Name*	*Duration (days)*	*Start*	*Finish*	*Predecessors*	*Resource Names*
Construction	Viranşehir	36	11.02.05	24.03.05	23FS+5d;74	Construction Group
	Araban	35	25.03.05	04.05.05	24FS+5d;75	Construction Group
	Islahiye	36	05.05.05	15.06.05	25FS+5d;76	Construction Group
	Karkamış	36	17.02.04	29.03.04	26FS+5d;1FS+143d	Construction Group
	Nizip	49	30.03.04	25.05.04	27FS+5d;78	Construction Group
	Nurdağı	35	26.05.04	05.07.04	28FS+5d;79	Construction Group
	Oğuzeli	36	06.07.04	16.08.04	29FS+5d;80	Construction Group
	Yavuzeli	36	17.08.04	27.09.04	30FS+5d;81	Construction Group
	Beşiri	41	28.09.04	13.11.04	31FS+5d;82	Construction Group
	Gercüş	35	15.11.04	24.12.04	32FS+5d;83	Construction Group
	Kozluk	49	25.12.04	19.02.05	33FS+5d;84	Construction Group
	Sason	49	21.02.05	18.04.05	34FS+5d;85	Construction Group
	Baykan	35	19.04.05	28.05.05	35FS+5d;86	Construction Group
	Eruh	41	30.05.05	15.07.05	36FS+5d;87	Construction Group
	Kurtalan	41	16.07.05	01.09.05	37FS+5d;88	Construction Group
	Pervari	41	27.01.04	13.03.04	38FS+5d;1FS+122d	Construction Group
	Şirvan	36	15.03.04	24.04.04	39FS+5d;90	Construction Group
	Musabeyli	36	16.06.05	27.07.05	40FS+5d;77	Construction Group
	Beytüşşebap	36	26.04.04	05.06.04	41FS+5d;91	Construction Group
	Cizre	49	07.06.04	02.08.04	42FS+5d;93	Construction Group
	İdil	35	03.08.04	11.09.04	43FS+5d;94	Construction Group
	Silopi	49	13.09.04	08.11.04	44FS+5d;95	Construction Group
	Uludere	36	09.11.04	20.12.04	45FS+5d;96	Construction Group
	Derik	36	21.12.04	31.01.05	46FS+5d;97	Construction Group
	Kızıltepe	49	01.02.05	29.03.05	47FS+5d;98	Construction Group

Table C.11 (cont'd)

Task Type	*Task Name*	*Duration (days)*	*Start*	*Finish*	*Predecessors*	*Resource Names*
Construction	Midyat	41	30.03.05	16.05.05	48FS+5d;99	Construction Group
	Midyatkesimi	36	17.05.05	27.06.05	49FS+5d;100	Construction Group
	Nusaybin	41	28.06.05	13.08.05	50FS+5d;101	Construction Group
	Ömerli	49	28.07.05	22.09.05	51FS+5d;92	Construction Group
	Savur	36	05.07.05	15.08.05	52FS+5d;65	Construction Group
	Yeşilli	36	15.08.05	24.09.05	53FS+5d;102	Construction Group
	Finish	0	24.09.05	24.09.05	105;103;104;89	

Table C.12 Cost risk model

Net floor area: 200 m2				
Cost item	*Most likely cost (million TL)*	*Minimum cost (million TL)*	*Maximum cost (million TL)*	*Simulated cost (million TL)*
Design	1500	1300	1800	1533
Labor	15000	13000	19000	15667
Material	25000	23000	30000	26000
Subcontractor	23500	20000	30000	24500
Overhead	10000	8000	14000	10667
Total cost	75000	65300	94800	[illegible]

Net floor area: 300 m2				
Cost item	*Most likely cost (million TL)*	*Minimum cost (million TL)*	*Maximum cost (million TL)*	*Simulated cost (million TL)*
Design	2000	1800	2300	2033
Labor	18000	15000	24000	19000
Material	32000	30000	38000	33333
Subcontractor	28000	25000	35000	29333
Overhead	11000	9000	15000	11667
Total cost	91000	80800	114300	[illegible]

Net floor area: 400 m2				
Cost item	*Most likely cost (million TL)*	*Minimum cost (million TL)*	*Maximum cost (million TL)*	*Simulated cost (million TL)*
Design	2500	2300	2800	2533
Labor	23000	20000	28000	23667
Material	40000	37000	44000	40333
Subcontractor	32000	29000	38000	33000
Overhead	12000	10000	16000	12667
Total cost	109500	98300	128800	[illegible]

Net floor area: 500 m2				
Cost item	*Most likely cost (million TL)*	*Minimum cost (million TL)*	*Maximum cost (million TL)*	*Simulated cost (million TL)*
Design	3000	2800	3300	3033
Labor	27000	24000	32000	27667
Material	50000	45000	57000	50667
Subcontractor	36000	32000	42000	36667
Overhead	13000	11000	16000	13333
Total cost	129000	114800	150300	[illegible]

Table C.12 (cont'd)

Net floor area: 600 m2				
Cost item	*Most likely cost (million TL)*	*Minimum cost (million TL)*	*Maximum cost (million TL)*	*Simulated cost (million TL)*
Design	3500	3200	4000	3567
Labor	30000	26000	36000	30667
Material	58000	55000	64000	59000
Subcontractor	40000	35000	47000	40667
Overhead	14000	12000	17000	14333
Total cost	145500	131200	168000	[illegible]

Net floor area: 1000 m2				
Cost item	*Most likely cost (million TL)*	*Minimum cost (million TL)*	*Maximum cost (million TL)*	*Simulated cost (million TL)*
Design	5000	4500	5800	5100
Labor	40000	35000	48000	41000
Material	90000	83000	100000	91000
Subcontractor	50000	45000	60000	51667
Overhead	16000	14000	19000	16333
Total cost	201000	181500	232800	[illegible]

Table C.13 Simulation results of cost risk analysis

	200 m2		300 m2		400 m2		500 m2		600 m2	
Percentile	Uncorrelated	Correlated	Uncorrelated	Correlated	Uncorrelated	Correlated	Uncorrelated	Correlated	Uncorrelated	Correlated
0%	69024	67157	84816	82796	102161	100013	118276	118125	136440	134144
10%	74522	73177	90783	89231	108285	106800	126455	125183	143205	141610
20%	75794	74676	92211	91032	109536	108403	128118	127190	144804	143630
30%	76723	75940	93330	92463	110498	109683	129292	128692	146005	145191
40%	77540	77200	94317	93788	111350	110831	130365	130017	147112	146627
50%	78371	78313	95201	94994	112192	111870	131384	131259	148151	147961
60%	79195	79449	96114	96321	113005	113063	132324	132520	149172	149347
70%	80058	80621	97164	97808	113852	114387	133354	133829	150162	150871
80%	81099	82146	98327	99488	114893	116150	134604	135540	151457	152739
90%	82628	84192	99917	101887	116274	118276	136419	137652	153230	155280
100%	89971	91961	108251	110390	122009	126184	145776	147013	164157	165502

	1000 m2	
Percentile	Uncorrelated	Correlated
0%	188197	185243
10%	198029	196284
20%	200300	198998
30%	201983	201086
40%	203426	203026
50%	204875	204723
60%	206340	206560
70%	207870	208466
80%	209643	210820
90%	212138	214165
100%	222636	227321

Note: All values are in million TL

Table C.14 Cash flow risk analysis model (for fixed tender price calculation)

Date	*Monthly Total Cash Outflow (current prices, million TL)*	*Simulated Inflation Rate*	*Monthly Total Cash Outflow (inflation adjusted, million TL)*	*Monthly Total Cash Outflow (profit added, million TL)*	*Total Cash Outflow (Fixed Price, million TL)*
May 2003	11.017,643	0,366666667	11.017,643	12.670,289	[redacted]
June 2003	195.045,838		195.045,838	224.302,714	
July 2003	126.459,155	Triangular distribution:	126.459,155	145.428,028	
August 2003	428.499,582	.....min: 30% (semi-anually)	428.499,582	492.774,519	
September 2003	220.500,208	.....likely: 35% (semi-anually)	301.350,284	346.552,827	
October 2003	510.345,677	.....max: 45% (semi-anually)	697.472,425	802.093,289	
November 2003	224.620,779		306.981,731	353.028,991	
December 2003	260.553,570		356.089,878	409.503,360	
January 2004	542.692,412		940.666,848	1.081.766,875	
February 2004	241.385,998		418.402,397	481.162,757	
March 2004	374.708,408		649.494,574	746.918,760	
April 2004	191.501,202		331.935,416	381.725,728	
May 2004	337.401,197		584.828,742	672.553,053	
June 2004	194.598,529		337.304,116	387.899,733	
July 2004	285.576,000		599.709,600	689.666,040	
August 2004	340.432,998		714.909,296	822.145,690	
September 2004	271.839,990		570.863,978	656.493,575	
October 2004	174.540,725		366.535,523	421.515,851	
November 2004	343.312,230		720.955,682	829.099,034	
December 2004	385.512,930		809.577,154	931.013,727	

Table C.14 (cont'd)

Date	*Monthly Total Cash Outflow (current prices, million TL)*	*Inflation Rate*	*Monthly Total Cash Outflow (inflation adjusted, million TL)*	*Monthly Total Cash Outflow (profit added, million TL)*	*Total Cash Outflow (Fixed Price, million TL)*
January 2005	194.598,529	0,366666667	480.009,704	552.011,160	[redacted]
February 2005	357.253,620		881.225,596	1.013.409,435	
March 2005	226.760,057	Triangular distribution:	559.341,475	643.242,696	
April 2005	212.896,908	.....min: 30% (semi-anually)	525.145,706	603.917,562	
May 2005	351.973,397	.....likely: 35% (semi-anually)	868.201,047	998.431,204	
June 2005	191.501,202	.....max: 45% (semi-anually)	472.369,631	543.225,076	
July 2005	321.391,337		910.608,789	1.047.200,107	
August 2005	210.893,964		597.532,899	687.162,834	
September 2005	360.272,706		1.020.772,667	1.173.888,567	

Table C.15 Cash flow risk analysis model (for net present value calculation)

Date	Monthly Total Completed Area, m2 = A	Completed Area Ratio = B =A/28200	Monthly Cash Inflow (retention excluded, million TL) = C = B*18860721,72*0,95	Monthly Retention Payment (million TL) = D = B*18860721,72*0,05	Montly Total Cash Inflow (retention included, mil. TL) = E = C+D	Monthly Total Cash Outflow (inflation adj.,profit exc., million TL) = F	Monthly Net Cash Flow (million TL) = G = E-F	Simulated Nominal Interest Rate = H	Simulated Nominal Interest Factor = I = 1/(1+H)**n	Monthly Net Present Cash Flow (million TL) = J = G*I	Total Net Present Cash Flow (million TL) = K = SUM (J)
May.03						11.017,643	-11.017,643	0,113333333	0,898203593	-9.896,087	[illegible]
June.03	500	0,017730496				195.045,838	-195.045,838		0,806769694	-157.357,071	
July.03	400	0,014184397	317.689,462		317.689,462	126.459,155	191.230,307	Triangular distribution:	0,724643438	138.573,787	
Aug.03	1700	0,060283688	254.151,569		254.151,569	428.499,582	-174.348,013	.....min: 9% (monthly)	0,650877339	-113.479,171	
Sept.03	1000	0,035460993	1.080.144,169		1.080.144,169	301.350,284	778.793,885	.....likely: 11% (monthly)	0,584620365	455.298,765	
Oct.03	2200	0,078014184	635.378,923	16.270,498	651.649,421	697.472,425	-45.823,004	.....max: 14% (monthly)	0,525108112	-24.062,031	
Nov.03	700	0,024822695	1.397.833,631	13.376,398	1.411.210,029	306.981,731	1.104.228,298		0,471653993	520.813,686	
Dec.03	900	0,031914894	444.765,246	56.849,693	501.614,939	356.089,878	145.525,061		0,423641311	61.650,428	
Jan.04	2400	0,085106383	571.841,031	33.440,996	605.282,027	940.666,848	-335.384,821		0,380516148	-127.619,340	
Feb.04	800	0,028368794	1.524.909,416	73.570,191	1.598.479,607	418.402,397	1.180.077,210		0,341780971	403.327,935	
March.04	1300	0,046099291	508.303,139	23.408,697	531.711,836	649.494,574	-117.782,738		0,306988896	-36.157,993	
April.04	600	0,021276596	825.992,600	30.096,896	856.089,496	331.935,416	524.154,080		0,275738529	144.529,475	
May.04	1200	0,042553191	381.227,354	80.258,390	461.485,744	584.828,742	-123.342,998		0,247669338	-30.548,279	
June.04	600	0,021276596	762.454,708	26.752,797	789.207,505	337.304,116	451.903,389		0,222457489	100.529,293	
July.04	900	0,031914894	381.227,354	43.473,295	424.700,649	599.709,600	-175.008,951		0,199812116	-34.968,909	
Aug.04	1200	0,042553191	571.841,031	20.064,598	591.905,629	714.909,296	-123.003,667		0,17947196	-22.075,709	
Sept.04	800	0,028368794	762.454,708	40.129,195	802.583,903	570.863,978	231.719,925		0,16120236	37.353,799	
Oct.04	500	0,017730496	508.303,139	20.064,598	528.367,737	366.535,523	161.832,214		0,144792539	23.432,097	
Nov.04	1200	0,042553191	317.689,462	30.096,896	347.786,358	720.955,682	-373.169,324		0,130053178	-48.531,857	
Dec.04	1200	0,042553191	762.454,708	40.129,195	802.583,903	809.577,154	-6.993,251		0,116814232	-816,911	
Jan.05	600	0,021276596	762.454,708	26.752,797	789.207,505	480.009,704	309.197,801		0,104922963	32.441,949	
Feb.05	1300	0,046099291	381.227,354	16.720,498	397.947,852	881.225,596	-483.277,744		0,094242182	-45.545,149	
March.05	800	0,028368794	825.992,600	40.129,195	866.121,795	559.341,475	306.780,320		0,084648667	25.968,545	
April.05	700	0,024822695	508.303,139	40.129,195	548.432,334	525.145,706	23.286,628		0,076031737	1.770,523	
May.05	1000	0,035460993	444.765,246	20.064,598	464.829,844	868.201,047	-403.371,203		0,068291979	-27.547,018	
June.05	600	0,021276596	635.378,923	43.473,295	678.852,218	472.369,631	206.482,587		0,061340101	12.665,663	
July.05	1100	0,039007092	381.227,354	26.752,797	407.980,151	910.608,789	-502.628,638		0,055095899	-27.692,777	
Aug.05	700	0,024822695	698.916,816	23.408,697	722.325,513	597.532,899	124.792,614		0,049487334	6.175,654	
Sept.05	1300	0,046099291	444.765,246	33.440,996	478.206,242	1.020.772,667	-542.566,425		0,044449702	-24.116,916	
Oct.05				20.064,598	20.064,598		20.064,598		0,039924882	801,077	
Nov.05				36.785,096	36.785,096		36.785,096		0,035860672	1.319,138	
Dec.05				23.408,697	23.408,697		23.408,697		0,032210185	753,998	
Jan.06				43.473,295	43.473,295		43.473,295		0,028931303	1.257,739	

Table C.16 Results of Table C14

Percentile	*Simulated Fixed Price (million TL)*
0%	16.562.468,482
10%	17.215.203,780
20%	17.472.628,117
30%	17.670.170,046
40%	17.854.583,148
50%	18.062.290,314
60%	18.287.382,225
70%	18.560.695,590
80%	18.860.721,720
90%	19.252.293,689
100%	20.137.681,482

Table C.17 Results of Table C15

Percentile	*Simulated Total Net Present Value (million TL)*
0%	1.054.528,241
10%	1.143.987,261
20%	1.186.812,574
30%	1.220.577,404
40%	1.252.376,745
50%	1.279.219,562
60%	1.304.574,326
70%	1.330.266,969
80%	1.359.386,083
90%	1.398.539,841
100%	1.503.666,841

Table C.18 Results of the competitive tender

Proposer (Design-Builder)	*Qualitative Score (out of 60)*	*Fixed-price Proposal (million TL)*	*Quantitative (Price) Score (out of 40)*	*Total Score (out of 100)*
Design-Builder A	48	18.860.721,72	40	88
Design-Builder B	55	20.530.623,00	35	90
Design-Builder C	43	19.523.432,20	38	81

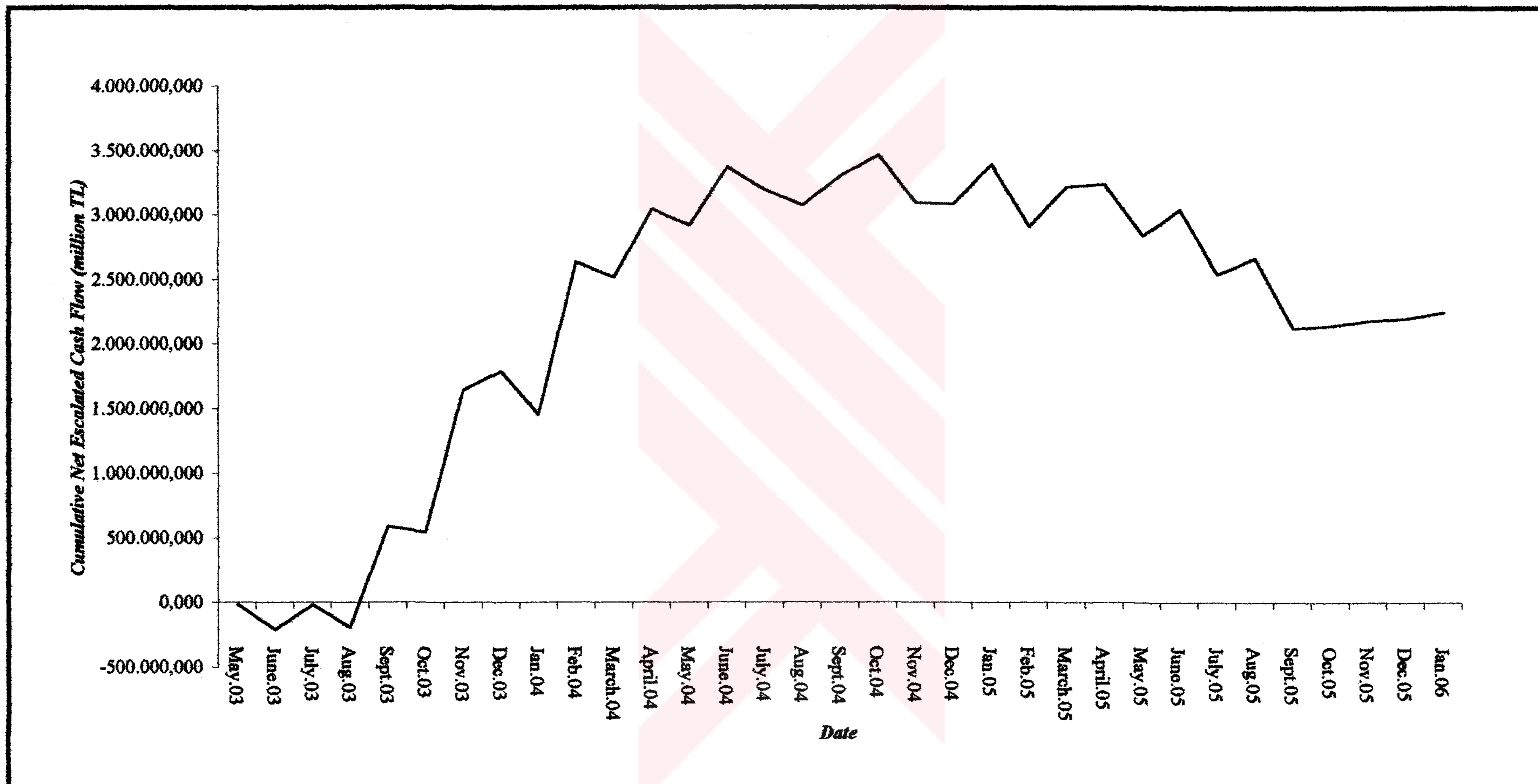

Figure C.1 Net cumulative cash flow chart

APPENDIX D

CASE STUDY II – ARCHITECTURAL PLANS

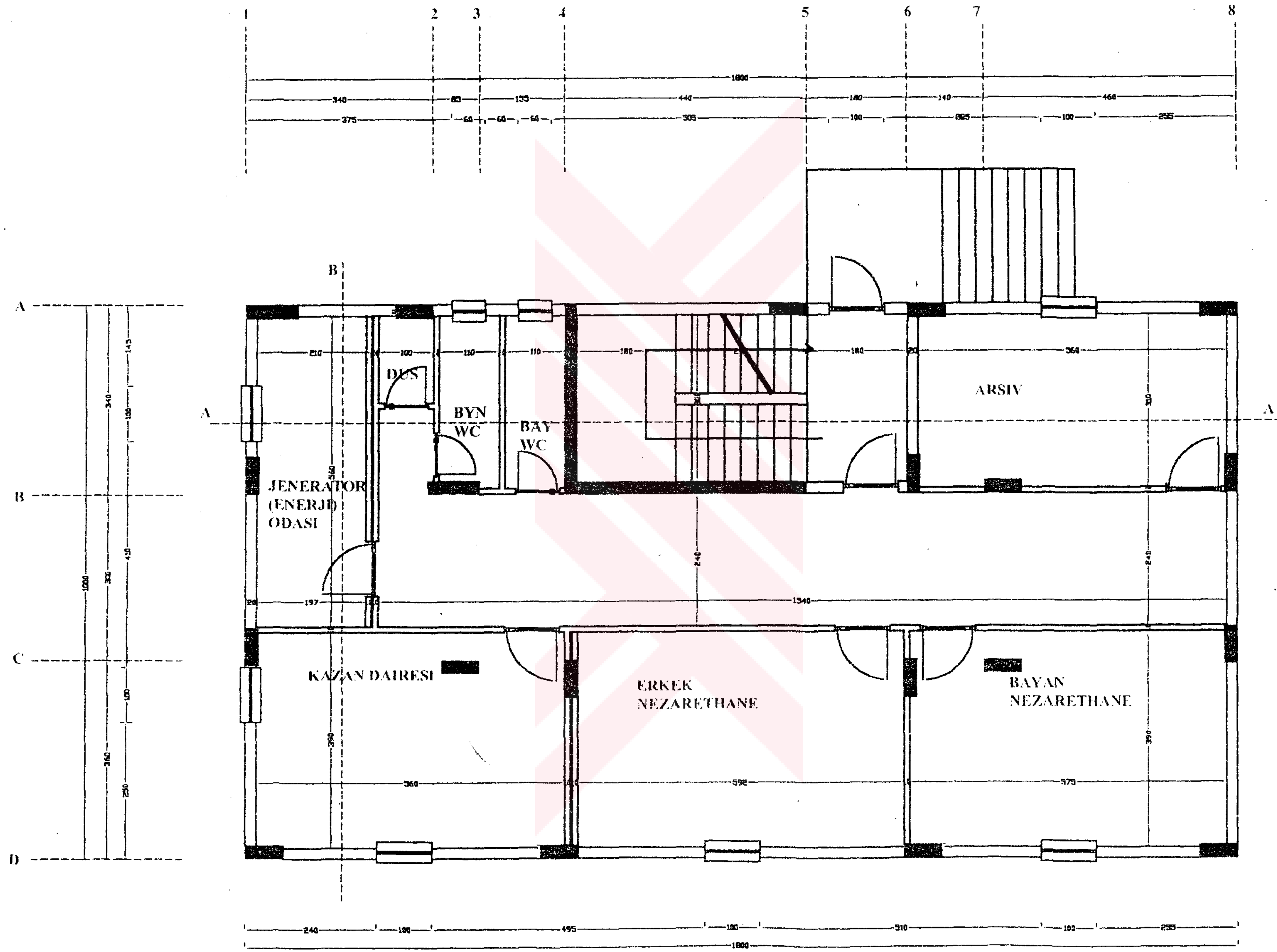

Figure D.1 Basement floor plan of the police station project

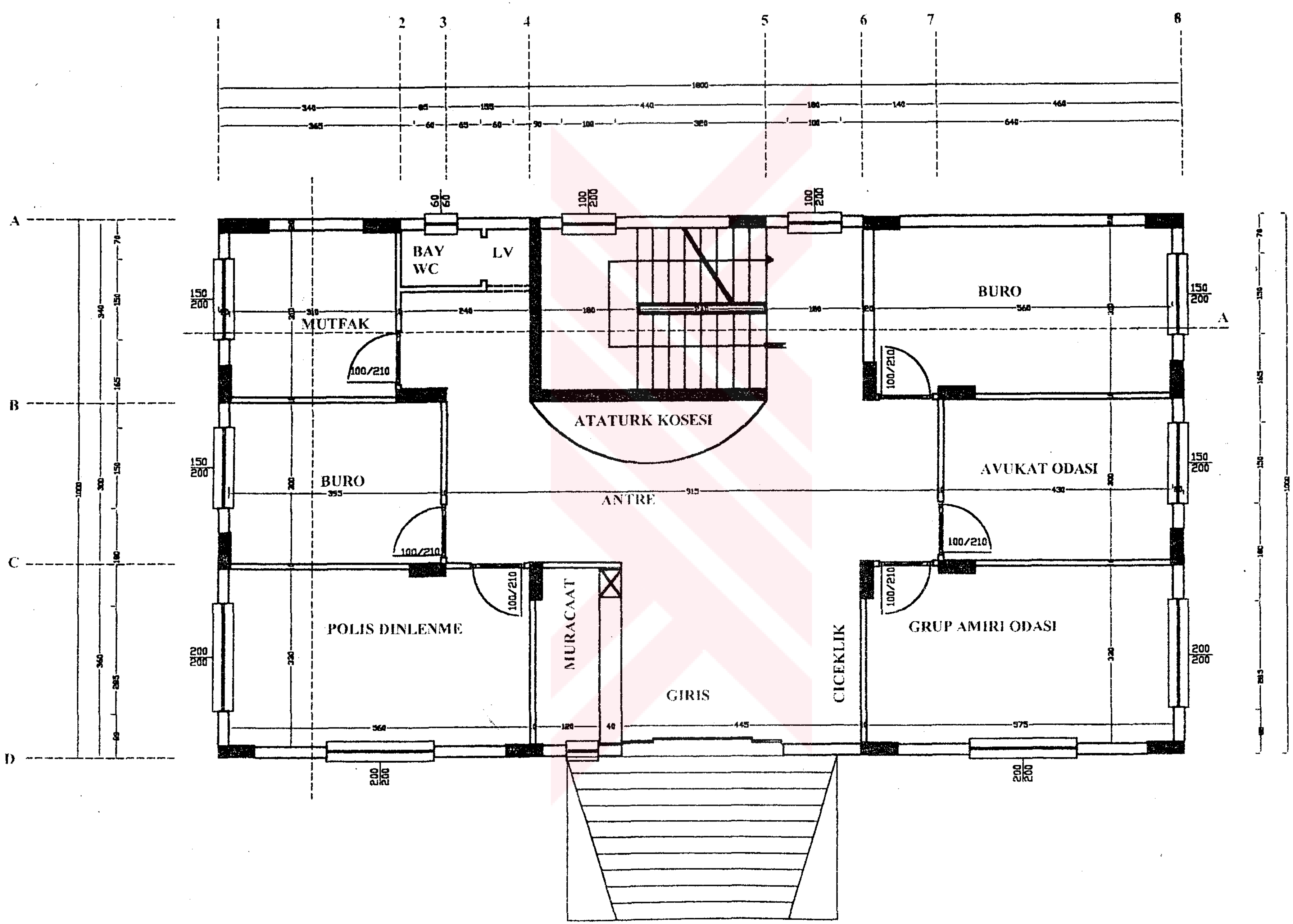

Figure D.2 Ground floor plan of the police station project

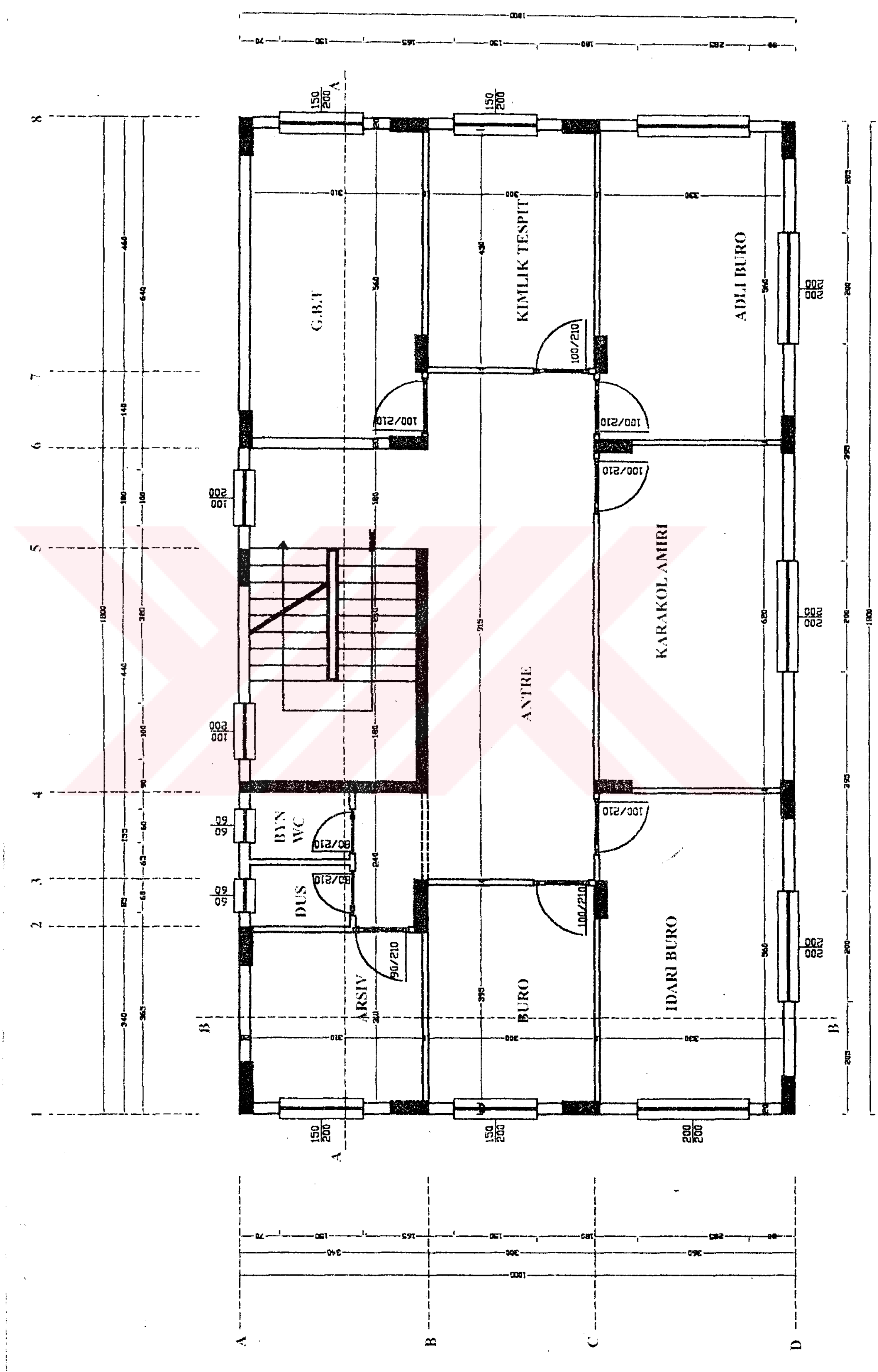

Figure D.3 First floor plan of the police station project

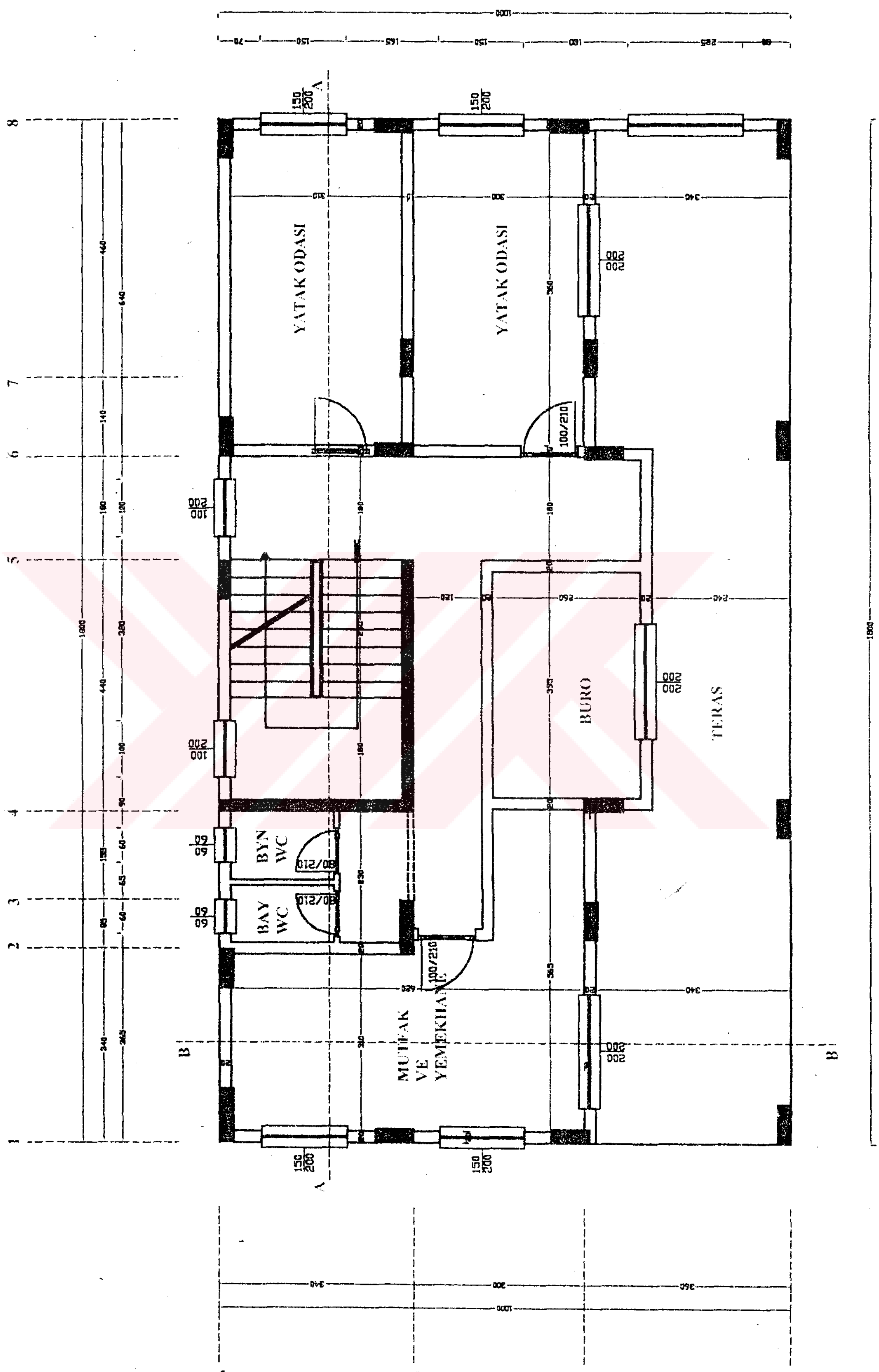

Figure D.4 Second floor plan of the police station project

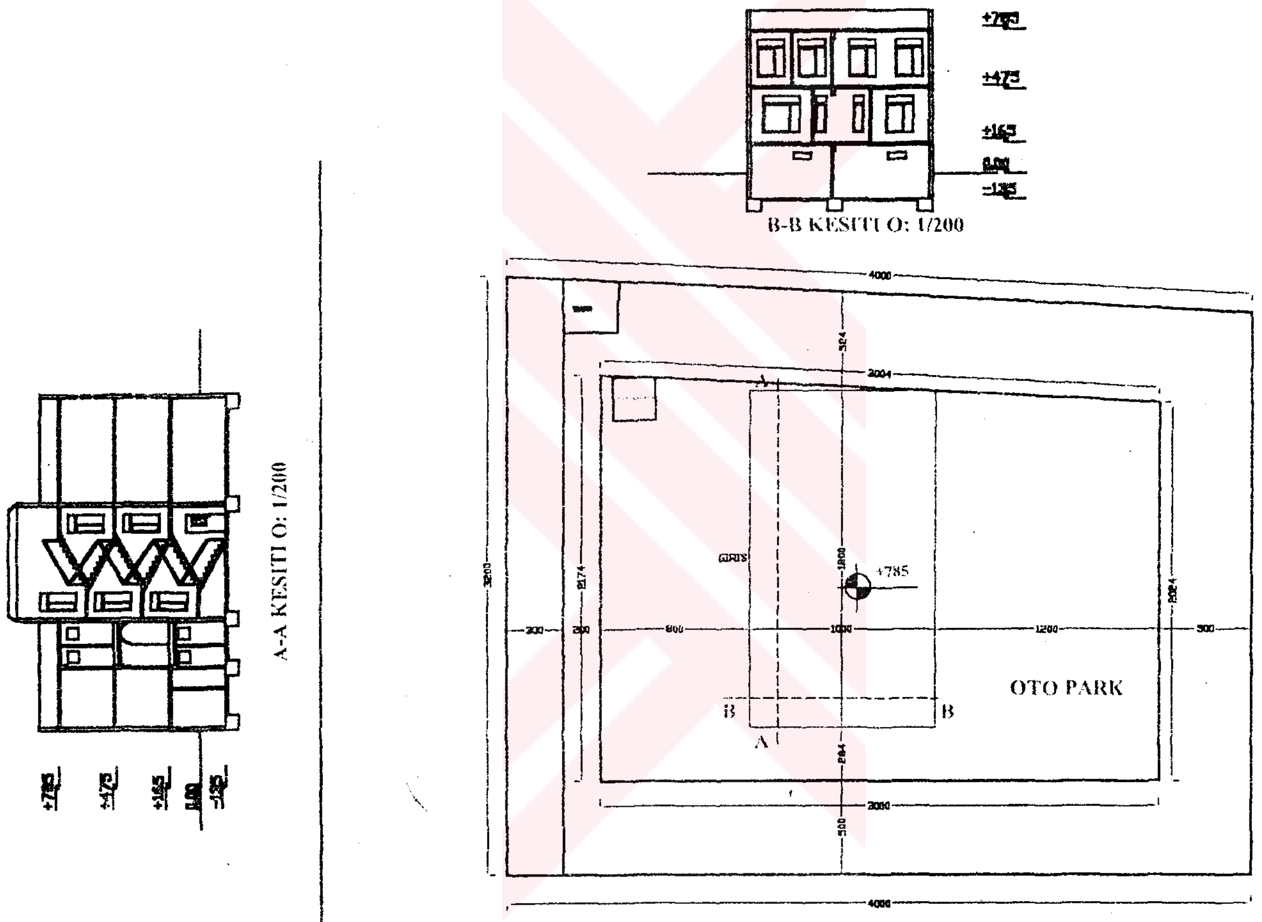

Figure D.5 Site plan of the police station project