RISK ANALYSIS OF BRIDGE CONSTRUCTION PROJECTS IN PAKISTAN

A Thesis

Of

Master of Science

Submitted By

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National Institute of Transportation

School of Civil and Environmental Engineering

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This is to certify that the

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TO

MY PARENTS

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ABSTRACT

Construction process is inherently prone to risks. Risk management is an essential and integral part of project management in construction projects. The remedy to manage construction project risks effectively lies in establishing a systematic risk management approach. Risk analysis is one of the core parts of the risk management, enables professionals to quantify and analyze risks, which may pose potential threats to project performance in terms of cost, quality, safety and time. This research attempts to identify and analyze risks associated with bridge construction projects in Pakistan during construction phase. A questionnaire survey was conducted to collect data. Risks affecting bridge construction projects performance were identified through interviews with engineers and managers involved with various bridge projects. Cost and schedule impacts of project risks were validated by conducting a case study using Monte Carlo simulation. The key findings indicate that financial and economic risks are a major factor in affecting cost and time objectives of project. The highest ranked factor identified is "unavailability of funds" with a relative importance index greater than 85. The results of Monte Carlo simulation were compared to the actual completion time and cost of activities on the case-study project. In all cases of this comparison, the actual completion date and cost fell within the predicted distribution by Monte Carlo simulation. The work provided risk analysis guidelines which comprised of a step by step process of performing a risk analysis on bridge construction projects. Results of this work can be very useful for planning and scheduling engineers, cost-control managers and project managers to evaluate particular risks on their projects and to avoid delays and cost overrun in any culture.

Table of Contents

CONTENTS **PAGE NO**

CHAPTER

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION

1.1 GENERAL

Risk is the quality of a system that relates to the possibility of different outcomes Schuyler, (2001) defines risk as the contingency event, which either happen or does not. Subsequently he argued that risk is a constituent of a threat and opportunity. Risk affects productivity, performance, quality and budget of a construction project (Akintoye and Macleod, 1997). Risk management is defined as a systematic controlling procedure for predicted risks to be faced in an investment or a project (Dikemen et al, 2004). In project risk management, strategy is to reduce the probability and impact of a threat and increase the probability and impact of an opportunity (Schuyler, 2001). Evidence has defined risk management as a stepwise procedure consisting of risk identification, risk classification, risk analysis, and risk response tasks (Flagnan and Norman, 1993). Risk analysis is defined by (Loosemore et al. 2006): the process of evaluating identified risks and opportunities to discover their magnitude, whether they merit a response, and how responses should be prioritized in the light of limited resources.

To cater for the needs of analyzing risks various techniques and models have been developed by researchers. Program evaluation and review technique (PERT) was devised by (Dept. Of the Navy 1958), it can be considered as a schedule risk analysis tool. Advanced Programmatic Risk Analysis and Management Model (APRAM) is an example of a decision support framework that can be useful for the management of the risk of project failures (Dillon and Pate-Cornell, 2001). Evaluating Risk in Construction – Schedule Model (ERIC-S): a comprehensive schedule risk model to estimate the pessimistic and optimistic values of activity duration based on project characteristics. (Nasir et al., 2003). Construction schedule risk analysis model (CSRAM): to evaluate construction activity networks under uncertainty when activity durations and risk factors are both correlated in between

(Ökmen and Öztas, 2008). These techniques either address the schedule risks, budget risks or both. Also some models like APRAM have been developed which analyze these risks along with technical risks such as quality.

1.2 PROBLEM STATEMENT

Management of risk on a formal level is a practice scarce in Pakistan (Ahmed et al., 2009). A recent study undertaken to investigate the current state of adoption of risks management practices in the construction industry of Pakistan showed that the contractors in Pakistani construction industry are generally not practicing formal risk management and majority of projects suffer from risk causes resulting in low productivity, poor quality and cost overruns (Farooqui et al. 2007). Pakistan has also faced the trauma of bridge failures and loss of life as a consequence in the Earthquake of 2005 and the recent Floods of 2010. The Sher Shah bridge, Karachi is one of the numerous projects that have either failed to serve the purpose for which they were constructed or failed because of improper design or construction. In the aftermath of these failures and of other constructed facilities, there is an increasing need for a thorough and effective risk analysis for all construction projects (Imbeah and Guikema, 2009). Infrastructure of a country depicts the economy. Bridges are an important part of the infrastructure. Bridges maybe either constructed to easy traffic on busy road in the form of flyovers or to facilitate traffic through a river. The literature gives the idea that a pioneering research presenting risk analysis guidelines for Pakistani bridge construction projects is the need of this developing construction industry.

1.3 RESEARCH OBJECTIVE

The main objective of this research is to identify and rank critical risks affecting the performance of bridge projects. Evaluate the effect of these risks on project cost and time with the help of a case study by Monte Carlo simulation method. This study is aimed to present a risk analysis guideline for professionals working on bridge construction project, in order to help them carry out the risk analysis for their respective projects.

1.4 SCOPE

The scope of this study is limited to the bridge construction projects in Pakistan and mainly covers key stakeholders i.e. clients, consultants and contractors. An effort has been made to include as many types of bridge projects as possible i.e. flyovers and bridges over rivers. Rawalpindi and Islamabad were the cities selected for a questionnaire survey and interviews.

1.5 ORGANIZATION OF THESIS

The thesis is organized in six chapters with chapter 1 covering an introduction to risk analysis and chapter 2 covering literature review, Chapter 3 covering methodology used in the research and chapter 4 covering test results. Chapter 5 covers discussion and analysis of these results. The final (6th) chapter deals with conclusions and recommendations.

Chapter 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter briefly presents the review of research literature already conducted on the topic of risk analysis in construction industry. Researchers on this topic have discussed different aspects of risk analysis. The study of the previous research will help in understanding the topic and will help in development of framework for this study to be conducted on the bridge construction projects in Pakistan.

2.1.1 Risk

The word “risk” came to English literature from French word “risqué” in mid seventeenth century. The insurance transaction started using Anglicized spelling in second quarter of eighteenth century (Flanagan and Norman 1999) and according to Loosemore et al. (2006) risk is concerned with unpredictable events that might occur in the future whose exact likelihood and outcome is uncertain but could potentially affect their interests / objectives in some way. Standards Association of Australia (1999) described risk as the chance of something happening that will have an impact upon objectives and is measured in terms of consequences and likelihood.

2.1.2 Risk Management

It is the culture, processes and structures that are directed towards the effective management of potential opportunities and adverse effects (Standards Association of Australia 1999). Loosemore et al. (2006) consider it to be the process of proactively working with stakeholders to minimize the risks and maximize the opportunities associated with project decisions.

2.1.3 Risk Management Process

It is the systematic application of management policies, procedures and practices to the tasks of establishing the context, identifying, analyzing, evaluating, treating, monitoring and communicating risk (Standards Association of Australia 1999).

2.1.4 Risk Identification

The process of determining what can happen, why and how (Standards Association of Australia 1999) and as per American National Standard (2004) it is the process of determining which risks might affect the project and documenting their characteristics.

2.1.5 Risk Analysis

A systematic use of available information to determine how often specified events may occur and the magnitude of their consequences (Standards Association of Australia 1999) and as per Loosemore et al. (2006) it involves systematically working through each of the risks and opportunities identified and recorded.

2.1.6 Qualitative and Quantitative Risk Analysis

Qualitative involves analysis of risks and opportunities using qualitative / descriptive scales such as high, medium and low and quantitative involves analysis of risks and opportunities using numerical estimates. Quantitative is normally conducted on risks and opportunities which emerge as particularly important from qualitative analysis and where reliable data for analysis is available (Loosemore et al. 2006).

2.1.7 Risk Response

Risk Response Planning is the process of developing options, and determining actions to enhance opportunities and reduce threats to the project’s objectives. It follows the qualitative risk analysis and quantitative risk analysis processes. It includes the identification and assignment of one or more persons (the “risk response owner”) to take responsibility for each agreed-to and funded risk response. Risk Response Planning addresses the risks by their priority, inserting resources and activities into the budget, schedule, and project management plan, as needed (American National Standard 2004).

2.2 RISK MANAGEMENT PROCESS

The risk management process is shown in Figure 2.1 and according to American National Standard (2004) it consists of five stages. First; the risk management plan which involves deciding how to approach, plan, and execute the risk management activities for a project. Second; risk identification which involves determining which risks might affect the project and documenting their characteristics. Third; risk analysis which is the process of evaluating identified risks and opportunities to discover their magnitude, whether they merit a response, and how responses should be prioritized in the light of limited resources. Fourth; risk control determines the process of developing options and actions to enhance opportunities and to reduce threats to project objectives. Fifth; risk monitoring and control which involves tracking identified risks, monitoring residual risks, identifying new risks, executing risk response plans, and evaluating their effectiveness throughout the project life cycle.

2.3 RISK IDENTIFICATION- INPUTS

As a prelude to risk identification one must understand and identify his objectives. The risk and opportunity identification process should commence while a decision is being made, rather than after it has been made, as is too often the case (Loosemore et al. 1993). The decision objectives must be identified first before the identification of risks and opportunities because risks and opportunities are future events that can affect objectives either positively or negatively. Unfortunately, many decisions are made automatically without a proper understanding of objectives which is one of the main reasons why many potential risks and opportunities are overlooked which can be avoided by following these steps as suggested by Loosemore et al. (2006) and American National Standard (2004) :-

- Obtain organizational commitment to risk and opportunity management.
- Conduct a stake holder analysis.
- Consult stakeholders.
- Identify objectives.
- Identify key performance indicators (KPIs).

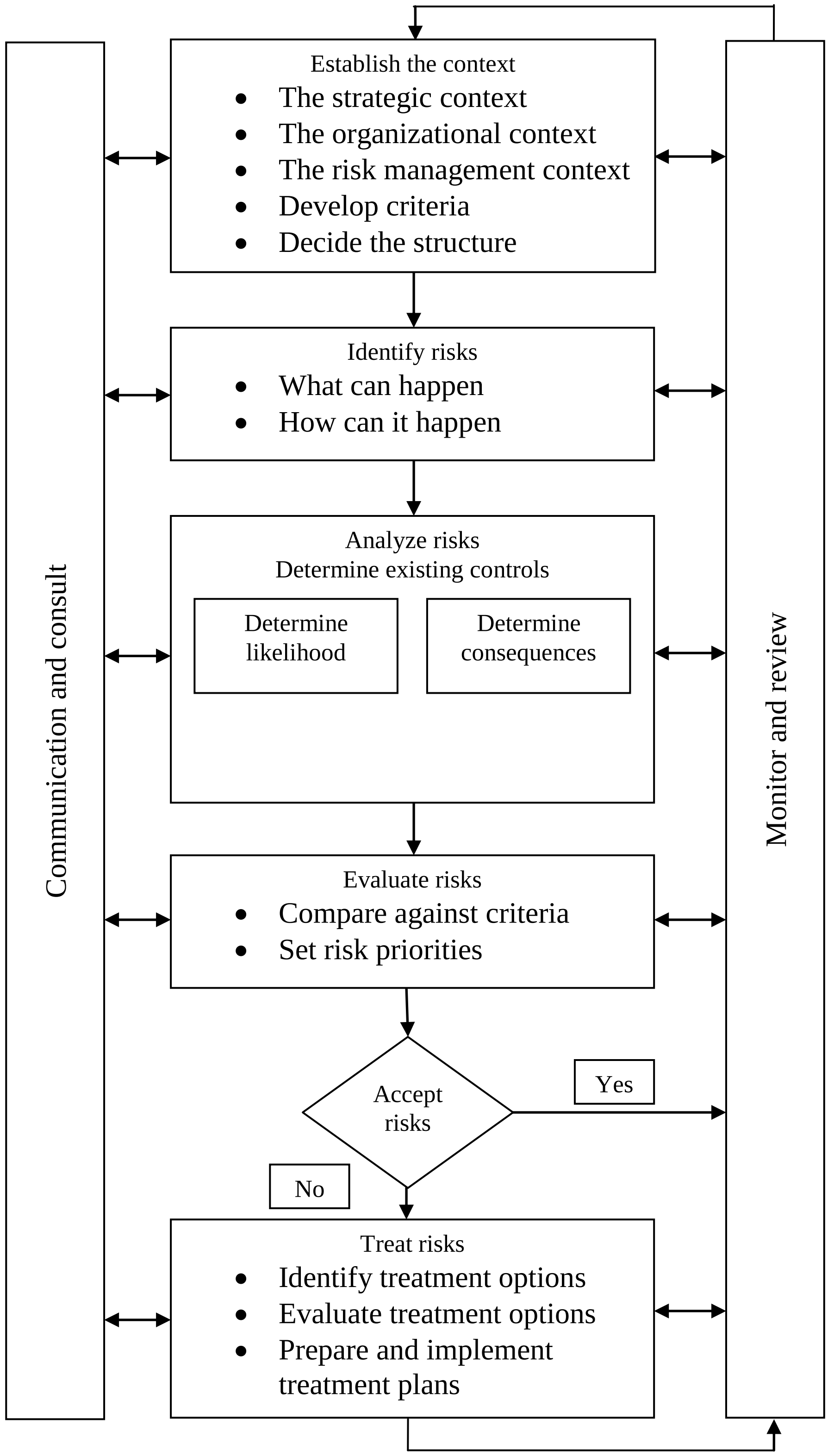

Figure 2.1: Risk Management Process (Standards Association of Australia 1999)

2.4 RISK IDENTIFICATION – TOOLS and TECHNIQUES

These techniques may be divided in proactive and reactive depending upon the time of their employment. Ideally the risk identification process should begin when the decision is being made using proactive risk identification techniques; however, it is not possible to identify all risks in advance regardless of the effort done to identify them. This entails that, risk identification should continue even after the decision has been made using reactive risk identification techniques. Loosemore et al. (2006) suggest following proactive risk identification techniques:-

- Employing and Using Creative People
- Creativity Training
- Organizational Characteristics
- Idea Elicitation Techniques
- Checklists
- Decomposition
- Forecasting
- Brainstorming
- The Delphi Technique
- Influence Diagrams
- Fault Tree Analysis
- Simulation

2.5 RISK IDENTIFICATION – OUTPUT

The outputs from risk identification are typically contained in a document known as risk register. The primary outputs from risk identification process are the initial entries into the risk register, which becomes part of the project management plan. The risk register ultimately contains the outcomes of the other risk management processes as they are conducted. The preparation of the risk register begins in the risk identification process and contains list of identified risks, list of potential responses, root causes of risk and updated risk categories as suggested by American National Standard (2004).

2.6 QUALITATIVE RISK ANALYSIS – INPUTS

The input to qualitative risk analysis as suggested by American National Standard (2004) include organizational process assets, project scope statement, risk management plan and risk register.

2.7 QUALITATIVE RISK ANALYSIS - TOOLS and TECHNIQUES

The tools and techniques as described in American National Standard (2004) include:-

2.7.1 Risk Probability and Impact Assessment

Risk probability assessment investigates the likelihood that each specific risk will occur. Risk impact assessment investigates the potential effect on a project objective such as time, cost, scope, or quality, including both negative effects for threats and positive effects for opportunities. Probability and impact are assessed for each identified risk. Risk probabilities and impacts are rated according to the definitions given in the risk management plan. Sometimes, risks with obviously low ratings of probability and impact will not be rated, but will be included on a watch list for future monitoring.

2.7.2 Probability and Impact Matrix

Risks can be prioritized for further quantitative analysis and response, based on their risk rating. Ratings are assigned to risks based on their assessed probability and impact. Evaluation of each risk's importance and, hence, priority for attention is typically conducted using a probability and impact matrix. Such a matrix specifies combinations of probability and impact that lead to rating the risks as low, moderate, or high priority. Numeric values (Table 2.1) or Descriptive terms (Table 2.2) can be used, depending on organizational preference. The organization should determine which combinations of probability and impact result in a classification of high risk, moderate risk and low risk. These conditions can be denoted by different shades of gray (Table 2.1). Usually, these risk rating rules are specified by the organization in advance of the project, and included in organizational process assets. Risk rating rules can be tailored in the risk management planning process to the specific project.

Table 2.1: Numeric Qualitative Risk Estimation (American National Standard 2004)

Probability and Impact Matrix

Probability	Threats					Opportunities				
0.90	0.05	0.09	0.18	0.36	0.72	0.72	0.36	0.18	0.09	0.05
0.70	0.04	0.07	0.14	0.28	0.56	0.56	0.28	0.14	0.07	0.04
0.50	0.03	0.05	0.10	0.20	0.40	0.40	0.20	0.10	0.05	0.03
0.30	0.02	0.03	0.06	0.12	0.24	0.24	0.12	0.06	0.03	0.02
0.10	0.01	0.01	0.02	0.04	0.08	0.08	0.04	0.02	0.01	0.01
	0.05	0.10	0.20	0.40	0.80	0.80	0.40	0.20	0.10	0.05

Impact (ratio scale) on an objective (e.g., cost, time, scope or quality)

Each risk is rated on its probability of occurring and impact on an objective if it does occur. The organization's thresholds for low, moderate or high risks are shown in the matrix and determine whether the risk is scored as high, moderate or low for that objective.

Table 2.2: Descriptive Qualitative Risk Estimation (Loosemore et al. 1993).

Probabilities	Consequences				
	Insignificant	Minor	Moderate	Major	Extraordinary
Almost certain	Low	Medium	High	High	High
Likely	Low	Medium	Medium	High	High
Possible	Low	Low	Medium	High	High
Unlikely	Low	Low	Low	Medium	Medium
Rare	Low	Low	Low	Medium	Medium

2.7.3 Risk Data Qualitative Assessment

A qualitative risk analysis requires accurate and unbiased data if it is to be credible. Analysis of the quality of risk data is a technique to evaluate the degree to which the data about risks is useful for risk management. It involves examining the degree to which the risk is understood and the accuracy, quality, reliability, and integrity of the data about the risk. The use of low-quality risk data may lead to a qualitative risk analysis of little use to the project. If data quality is unacceptable, it may be necessary to gather better data. Often, collection of information about risks is difficult, and consumes time and resources beyond that originally planned.

2.7.4 Risk Categorization

Risks to the project can be categorized by sources of risk, the area of the project affected or according to project phases to determine areas of the project most exposed to the effects of uncertainty. Grouping risks by common root causes can lead to developing effective risk responses.

2.7.5 Risk Urgency Assessment

Risks requiring near-term responses may be considered more urgent to address. Indicators of priority can include time to affect a risk response, symptoms and warning signs, and the risk ratings.

2.8 QUALITATIVE RISK ANALYSIS – OUTPUT

Its output is in the shape of updating of risk register which was initiated during the risk identification process. The risk register is updated with information from qualitative risk analysis and the updated risk register is included in the project management plan. American National Standard (2004) recommends that the risk register updates from qualitative risk analysis may include relative ranking or priority list of project risks, risks grouped by categories, list of risks requiring response in the near future, list of risks for additional analysis and response, watch lists of low priority risks and trends in qualitative risk analysis results.

2.9 QUANTITATIVE RISK ANALYSIS – INPUT

The input to quantitative risk analysis includes organizational process assets, project scope statement, risk management plan, risk register and project management plan as suggested by American National Standard (2004).

2.10 QUANTITATIVE RISK ANALYSIS – TOOLS and TECHNIQUES

Loosemore et al. (2006) suggests following techniques for quantitative risk analysis:-

2.10.1 The Risk Premium

The risk premium is a rather coarse, but widely used, instrument which is also known as the contingency fund. Indeed, in industries such as construction, it would be regarded as negligent if any consultant produced an estimate or project forecast which did not include a contingency fund. This is testimony to the fact that in many industries such as construction, risks have long been accounted for as a matter of course. In these industries, the usual practice is to add a contingency premium to the base estimate to account for downside risks, accepted by the organization which cannot accurately be forecast at the time. However, in practice, the way in which contingency allowances are calculated is often problematic. Calculations rarely take account of risk attitude, are often arbitrary and are not tailored to the specific project. For example it is found that in the construction industry, many contingency estimates are seen as a routine administrative procedure underpinned by little investigation on the part of the estimator. Not only does this result in highly subjective estimates, there is a tendency to double count risk because some estimators also subconsciously include for them in their base estimates. The result of these deficiencies is all too often the rejection of projects that are economic and the submission of overly conservative bids which are unsuccessful or inflated prices for clients when they are successful. A potentially greater problem is that such allowances can hide poor management and the potential for greater efficiency. So in summary, the risk premium is at best a rather blunt tool that is made less effective because it is also not used very effectively in practice.

2.10.2 Sensitivity Testing

Sensitivity tests measure the effect on a decision output, of certain specified changes in the value of input variables (risks). For example, if the decision is to arrive at a contingency allowance for a tender, one may alter interest rates, energy costs, labor costs, construction period etc as input variables to see what impact various percentage changes in each of these variables would have on project costs. This will reveal what input variables (risks or opportunities) project cost is most sensitive to. For example, a 5 percent change in one variable may produce a 50 per cent increase in costs whereas a 5 percent change in another variable might produce no change in costs. Clearly, the bigger risk variable which merits special attention is the one which produces the 50 per cent change. Furthermore, if costs increase when a variable in changed then it is a risk, but if costs fall then the variable is an opportunity (assuming that the objective is to minimize costs). Nevertheless, sensitivity testing, when interpreted correctly and conducted realistically, can convey an extremely useful picture of a project / investment decision under dynamic real world conditions. There are several advantages to the use of sensitivity testing. It is quick and easy to use. It requires little information and it can usually be carried out by hand. Furthermore, it fully recognizes uncertainty in the input variables and can show how the output will be influenced by changes in input variables either singly or in combination. However, there are also several limitations with this method. For example, it takes no account the likelihood of the range of input and output variables. Therefore, does not give a probabilistic picture of risk exposure and there is no explicit method of allowing for risk attitude. For this reason, it has been argue that the results of sensitivity tests are at best ambiguous and at worst misleading. They are said to be ambiguous because they do not suggest how likely it is that the pessimistic or optimistic results will occur. They can also be misleading when some analysts unrealistically take a number of very low probability worst or best case values of input variables and calculate the effect on the output. Such combinations produce extremely low probabilities, are very unlikely in the real world and such a test would produce exaggerated results.

2.10.3 Expected Monetary Value (EMV)

A simple way of incorporating probability into risk analysis is the EMV method. It is often very useful for companies, in making decisions, to express their risks in dollars. Although this is not always possible with reliable accuracy the resultant value is commonly referred to as the expected monetary value (EMV) of a decision. When calculating EMV, it is important to appreciate that every event has a range of possible outcomes (consequences), each with a different probability of occurring. So far we have simplistically assumed that any event has only one possible outcome with an associated probability of occurring. This range of possible outcomes is called a probability distribution. For example, consider a lottery ticket which gives the owner a 0.75 chance of winning \$5000 and a 0.25 chance of winning nothing. The expected monetary value (EMV) of the ticket is given as:

$$EMV=0.75 \times \$5000 + 0.25 \times \$0 = \$3750$$

This implies that over a large number of transactions, I can expect to make \$3750 from purchasing such lottery tickets. The significance of this EMV calculation is that it tells us there is no risk in spending \$3750. It also tells us that if I spend more than \$3750 then I can expect to lose money and the more I spend over this amount, the more risk I incur. While valuable, it is important to appreciate that EMVs, when based on objectively derived probabilities, are only meaningful in the context of a large number of identical transactions. Unfortunately, it is sometimes used inappropriately to assess decisions of a more unique nature, which change over time. The advantage of the EMV method is that it considers all possible outcomes and avoids simply combining all the best and the worst cases to produce unrealistic extremes of possible outcomes. The EMV method is also suitable for a range of applications - budget figures, tender price forecasts, rates of project return or completion dates. It also overcomes some of the limitations of sensitivity testing by explicitly allowing for the probability of change in input values - producing a risk-adjusted outcome. The limitation of EMV, when based on objective probabilities, is that it is best used consistently over many similar-sized projects. The guidance it provides is helpful, but strictly, only in the very long run.

2.10.4 EMV using a Delphi Peer Group

One of the issues in using any probabilistic technique is how to arrive at the probability values. The Delphi method is named after the oracle at Delphi in ancient Greece. It utilizes a formal Delphi group and is designed to pool the expertise of many professionals in order to gain access to their knowledge and technical skills while removing the influences of seniority, hierarchies and personalities on the derived forecast. It also eradicates the biases of overconfidence which may encroach on expert forecasts. First, a group of experts is identified. The group members are kept separate to prevent any personal interaction, and the coordinator asks each member to make a forecast and a subjective probability estimate for the relevant components of the project or decision under consideration. The coordinator receives and summarizes these estimates and the summary is given back to the members without any names attached. The group members are then asked to amend their forecasts in the light of the summary information. The new forecasts are then revised and communicated to all members. This process of forecast, summary, amendment and feedback continues until there is a consensus or when the members no longer wish to amend their forecasts. The result is the Delphi forecast and there is no doubt that this is a powerful method of assessing important projects at the budget and feasibility stage. In many projects it can easily be conducted using email over the course of one afternoon. The advantage of adding the Delphi group to the EMV method is that it is a well recognized method of getting the best out of a group of experts in a forecasting situation. The limitation is the extra resources and time it takes to undertake. Also, participants may not have a similar window of time in order to undertake the process simultaneously. Therefore risks and size of a project should be sufficient to warrant the effort required.

2.10.5 Expected Net Present Value (ENPV)

The ENPV approach is useful in investment and development appraisal and can be applied in a wide range of situations where future income or cost flows are known. For example, it is used by the Victorian Government in Australia to evaluate tenders for PPP projects covering periods of up to 30 years. ENPV is also the basis of life cycle costing technique. ENPV is based on the combination of probability analysis and the corporate financial technique of discounted cash flows (DCF) which has been developed to convert future income or cost flows back to net present day values. The DCF technique is based on the assumption that the value of money diminishes over time due to a number of factors including inflation, taxation and earning potential. These factors mean that a dollar today is worth more than a dollar in the future. This is reflected in ENPV calculations by using a discount rate (a percentage figure which reflects these factors) to convert future cost or revenue streams back to current day (present) values, thereby facilitating single point comparisons between different investment opportunities or risks. Essentially, an ENPV figure is the amount that would be needed today to purchase an equivalent amount of goods and / or services at some point in the future. So if a building component costs $1000 to repair in 10 years time, the ENPV of that repair cost is the equivalent amount it costs today to carry out that exact repair. Given that inflation will invariably increase repair costs over the 10 year period, the ENPV figure of an equivalent repair today will always be less than $1000. So the discount rate can be based on a number of factors which determine how the value of money changes over time. These include future rates of inflation, taxation rates, affordability rates and investment rates (interest rates, bond rates or equity rates) that determine how a dollar invested now can grow in value over the period being considered. For example, the discount rate used by the UK government and Australian Victorian State Government for the economic appraisal of PF1 and PPP projects respectively has been 6 percent per annum - the average rate of return from government investments. In 2003 the UK changed its PFI discount rate to 3.5 per cent to reflect society's time value of money (inflation). Coincidentally, Australia also changed its discount rate to a flexible one, based on the perceived level of risk on each project (the extent to which costs could escalate and erode the real value of money in terms of the physical assets it buys). The example given here is for investment appraisal but the same approach could be used for the development appraisal of a new building or an infrastructure project.

2.10.6 Risk Adjusted Discount Rate (RADR)

This is an intuitive and very simple method of dealing with risk, which is commonly used in banking and business for investments that produce an income stream over a period of time. The method is not well understood in construction but could be a very useful way of dealing with both risk exposure and risk attitude, especially for life cycle costing decisions and revenue / cost flows in PFI and PPP projects. The RADR works by gradually changing the discount rate to take account of the normal risk encountered in a development. Each increase in the discount rate effectively sets a higher hurdle for the project, making it less desirable by reducing the calculated net present value (NPV) of future income.

2.10.7 Detailed Analysis and Simulation

Simulation is a sampling technique that randomly draws values from the full range of individual probability distributions developed for each decision on a project, providing the systematic evaluation of alternative project strategies and outcomes and the search for the optimum one. Traditionally, the Monte Carlo technique is used as the statistical basis for such analysis. Although many managers have heard of this simulation technique, it conjures up images of a complex analytical tool that is difficult to use. Nevertheless, the Monte Carlo technique is quite simple in principle and recognizes individual variables within a calculation as probability distributions rather than single numbers. By using Monte Carlo simulation, probability distributions for any decision (as defined by the estimator) can be randomly combined using random number to produce a complete judgment about the entire range of potential events. This produces a multi point estimate reflecting the likelihood of each value in that range. Using a simulation program (probably built on the back of a spreadsheet such as Excel) a project is "built" many times, with random variations of the input variables defined in the input probability distributions for each decision in a project. The simulation results in a statistical sample of different project outcomes with identical probabilistic characteristics. Analysis of this sample enables us to attach some numeric evaluation to the degree of risk in an estimate.

2.11 QUANTITATIVE RISK ANALYSIS – OUTPUT

The main output is in the form of updating of risk register. The risk register is initiated in the Risk Identification process and updated in the process of qualitative risk analysis. It is further updated in quantitative risk analysis. The risk register is a component of the project management plan. Updates as suggested by American National Standard (2004) include probabilistic analysis of the project, probability of achieving cost and time objectives, prioritized list of quantified risks and trends in quantitative risk analysis results.

2.12 MONTE CARLO SIMULATION

Schuyler (2001) describes, Monte Carlo (MC) simulation is perhaps the most popular of the various management science techniques. The simple, elegant method provides a means to solve equations with probability distributions.

We credit legendary mathematician **John von Neumann** (originally Johann, 1903-1957) with popularizing the Monte Carlo technique, while participating in the design of the atomic bomb. He recognized that a relatively simple sampling technique could solve certain mathematical problems that are otherwise impossible. Among the applications is solving for EV, the probability-weighted average of a probability distribution. A valuable side-benefit is that we easily obtain approximate outcome probability distribution shapes. Simulation depends upon two essential elements:

1. A model that projects project outcome and outcome value.
2. A technique that repeatedly generates scenarios, driven by randomly sampling input probability distributions. The details follow.

2.12.1 Inputs as Distributions

Probability distributions express expert opinions about uncertainties. An expert's forecast for time to complete an activity is better as a distribution than as a single-value estimate. The distribution completely represents the expert's opinion about the outcome range and the relative likelihood of values within that range.

The foundation for simulation is a ***random sampling process.*** We generate many possible project scenarios (trials). Then, we examine the distributions of trial outcome values. Trials, in sufficient number, preserve the characteristics of the original probability distributions and approximate the solution distributions.

The simulation process is appealing because it is easily understood and not a black-box solution. We can inspect any trial result to determine what combination of input values led to this outcome scenario projection. A simulation model is a straightforward extension to the customary, single-valued deterministic model (so-called because every input is singly determined). This is why simulation persists as perhaps the most popular technique in operations research/management science.

Every trial pass through the model generates a plausible scenario. Extreme cases can be examined to see what conditions gave rise to these ***outlier*** results. Examining outliers is a powerful method of validating the model.

Figure 2.2 shows, conceptually, how we extend a conventional, deterministic model for a simulation analysis. The deterministic model sometimes needs little modification to prepare for simulation. We only need changes necessary to ensure that the model's calculations are valid over all possible ranges and combinations of input values.

If one or more inputs to the model are probability distributions, then the outputs will be probability distributions also. Instead of a single outcome value, such as a present value (PV), simulation yields a distribution for value. We can generate projections for time spread variables, such as net cash *flow*, and display them as EV and confidence curves.

2.12.2 Simulation Process

An iterative loop surrounds the deterministic project model and controls the process-generating many plausible "trial" solutions. Figure 2.3 is a flow diagram of a simulation. Most of the action is at the left, where the system performs many trials. Each trial is a pass through the steps at the left, and generates a possible case for the behavior of the project. The program generates many cases until a predetermined number of trials, or until a stopping ***rule*** condition, is satisfied. Typically, several hundred trials are necessary to obtain enough data for reasonable precision in the EV calculation.

Here is a typical sequence of steps in the simulation process:

1. Sample probability distributions representing the several random, or stochastic, variables.
2. Substitute the trial values of the random variables into the deterministic model. Resolve the model, obtaining project results and outcome values.
3. Store preselected outcome values, e.g., time and cost to complete, in a data file.
4. Return to Step 1 and repeat until the number of trials is sufficient to provide the required level of precision.
5. Analyze the stored results.

When the trials are complete, we analyze the generated synthetic data. Averaging trial values approximates EVs. Frequency distributions and time spread variable confidence bands are easy to obtain-for example, the PV distribution shown in the lower left of Figure 2.3.

Averaging the PV outcomes ***approximates*** the expected monetary value (EMV). The precision of the EV and probability distribution shape approximations improves as we increase the number of trials.

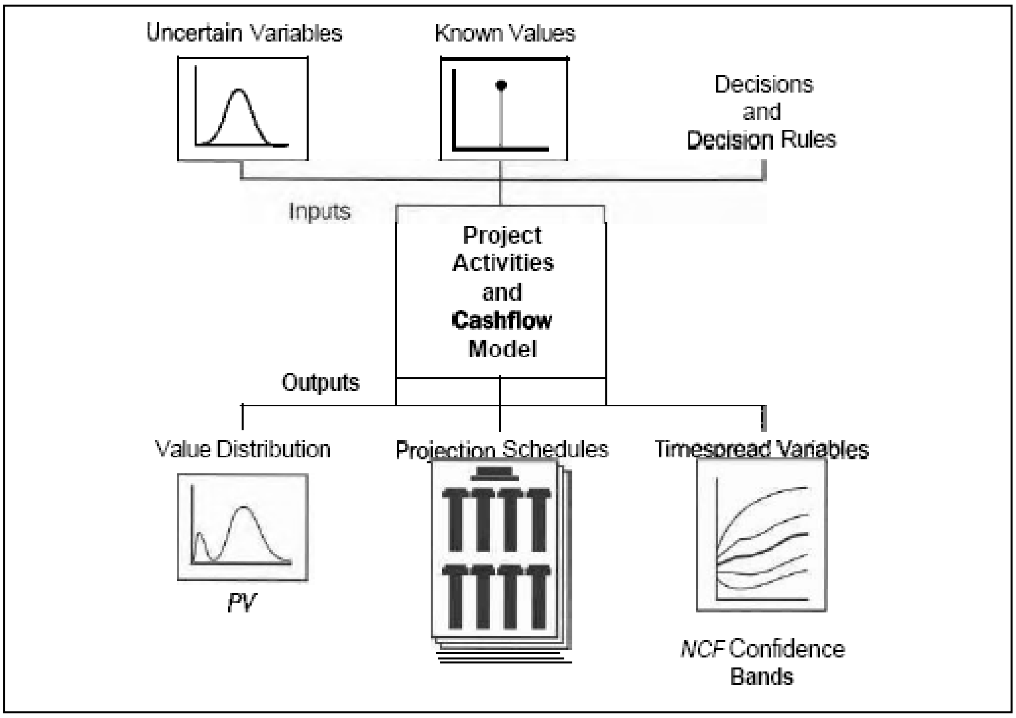

Figure 2.2: Stochastic (Probabilistic) Model

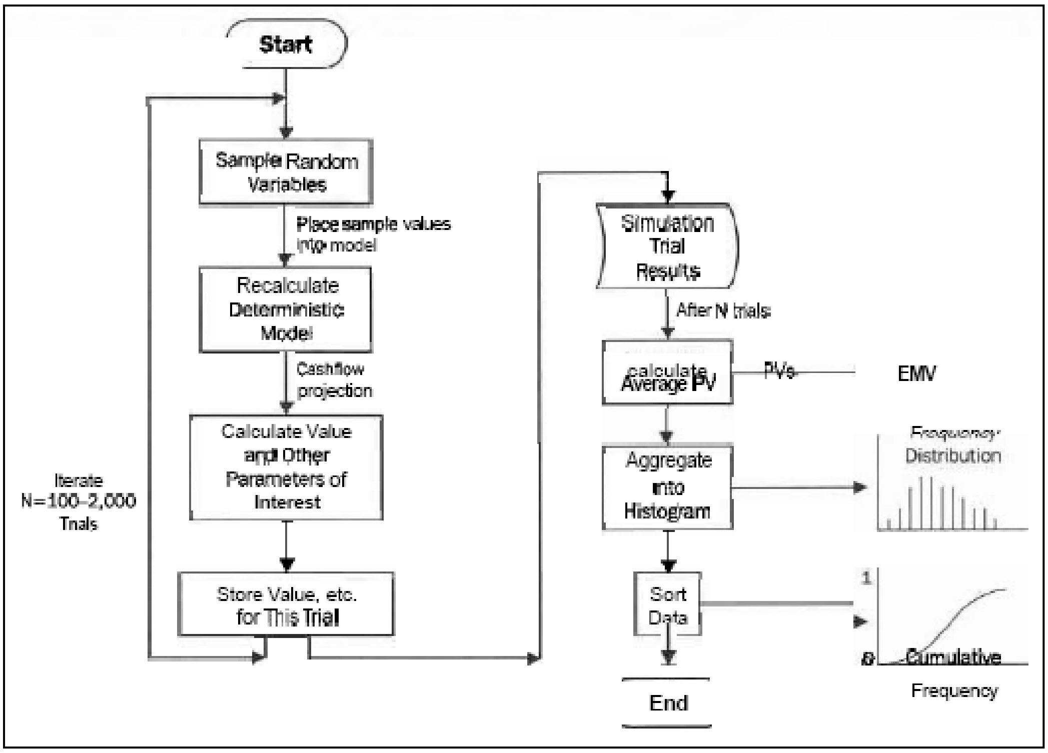

Figure 2.3: Simulation Flow Diagram

The EMV may be sufficient information for decision making. However, in the spirit of full and clear communication, it is good practice to include the PV distribution in the analysis presentation. Different distribution formats are available:

Aggregating PVs into groups by size and displaying the values as a frequency histogram provides the approximate shape of the PV probability (density) function. Sorting PVs by magnitude and displaying PV as a function of rank yields the cumulative frequency distribution. These frequency distributions approximate the shape of the solution probability distributions.

2.12.3 How Random Sampling Works

We obtain sample, or trial, values for chance variables by a simple process. In simulation, we often call these random variables, because a random number generator drives the sampling process. Synonyms include chance variable and stochastic variable. We will look at conventional Monte Carlo sampling for continuous and discrete events.

2.12.4 Discrete Distribution

Figure 2.4 shows three-level distribution. [There are many combinations of branch outcome values and probabilities that will provide the same target mean and standard deviation.] With simulation, we can avoid this discrete abstraction: we can represent the full range of possible outcomes of any uncertainty. However, for illustration, let's look at how we could sample the discrete Time to Complete Other Activities distribution in a simulation.

A random number function provides a random sampling parameter between zero and one. Most random number generators, such as the RAND () function in Excel; provide a uniform distribution with equally-likely values in the range, zero to one.

To set up the discrete distribution for sampling, divide the zero-to-one interval into segments whose widths correspond to the probabilities of different outcomes, as illustrated in Figure 2.4.

Each partition's width corresponds to the probability of the corresponding outcome. The example logic works like this:

RN = random number

If RN< .3, then

Time to Complete Other Activities = 3 months

else if RN < .7, then

Time to Complete Other Activities = 4 months

else

Time to Complete Other Activities = 5 months.

When using Monte Carlo simulation, we seldom would use a discrete approximation for a continuous event. "Risks," however, are often binary: either the risk event happens or not. This is easy to simulate with logic such as:

Probability of Weather Delay = .24

RN = random number

If RN < Probability of Weather Delay, then

Weather Delay = True.

If true, then we could apply a time, cost, or other impact in the form of a continuous distribution, as explained next.

Time to Complete Other Activities	Probability
3 months	
4 months	
5 months	

Figure 2.4: Three-Level Input Distribution

2.12.5 Continuous Distribution

After an expert takes time to judge Time to Complete Other Activities, she would normally express her opinion as a probability distribution. Consider the probability density function in Figure 2.6. This is a normal (Gaussian) distribution shape, with $\mu = 4$ months and $\alpha = .775$ month. This distribution is this expert's forecast for this variable.

In the decision tree analysis, Time to Complete Other Activities was abstracted into the three-value discrete distribution, shown in Figure 2.5. With simulation, we do not need to convert the form of the original distribution if it was a continuous distribution. In simulation, we can represent the full range of possible outcomes.

Simulation software often allows directly entering the probability density distribution as an input assumption. Do not worry about the actual calculation method. Conceptually, the sampling process uses the cumulative form of the distribution.

Figure 2.5: Sampling a Discrete Distribution

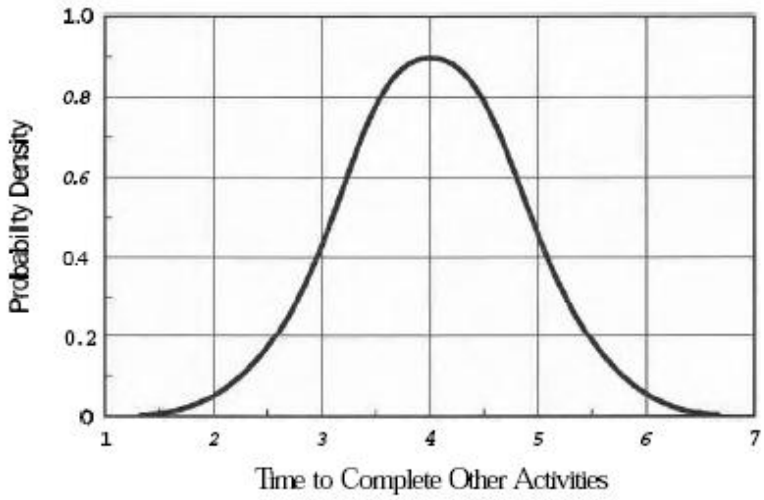

Figure 2.6: Probability Distribution for One Input

We want to convert the density curve of Figure 2.6 into the cumulative curve of the probability density distribution has a normalization requirement that the area under the curve equals 1. We obtain the cumulative distribution by adding the area (i.e., integrating) under the probability density function from left to right.

Both Figure 2.6 and Figure 2.7 fully represent someone's judgment about the uncertainty, Time to Complete Other Activities. The cumulative form is more convenient for our present purpose. For any Time to Complete, t, on the x-axis, the curve intercept is the probability that the outcome will be less than t.

Refer to Figure 2.7 for this explanation of how (traditional) Monte Carlo sampling works for a continuous distribution. On a single pass through the simulation model, we want to determine a trial value for this activity completion time. Most random number generators produce a number corresponding to a zero-to-one uniform distribution. This is the sampling parameter and, conveniently, maps to the cumulative probability axis. To obtain a trial value for this variable:

1. Enter the y-axis at the sampling parameter (random number).

2. Move rightward to the cumulative curve.

3. Move down to the corresponding value on the x-axis. This x-axis value is the trial value for this variable.

Suppose the random number generator provides a value of .685. As indicated in Figure 2.7, this corresponds to 4.4 weeks on the x-axis. We substitute this trial value into the deterministic project model. We next obtain trial values for the other random variables in similar fashion, using a different random number for each variable. We then solve the model for a trial projection. This is but one particular scenario in the simulation run.

Note that if we sample an input distribution many times and graph the values in a frequency histogram, then the shape will approximate the original probability distribution. The key to simulation is that this random sampling process preserves the character of the original distributions. The match improves with more trials and finer histogram divisions.

If we sample a distribution many times and average the result, the average approximates EV. The simulation process performs the integration for us-approximately. We need simulation because for most evaluation problems of interest, the integration defies direct mathematical solution. Thus, Monte Carlo simulation is solving a very difficult, if not impossible, calculus problem for us.

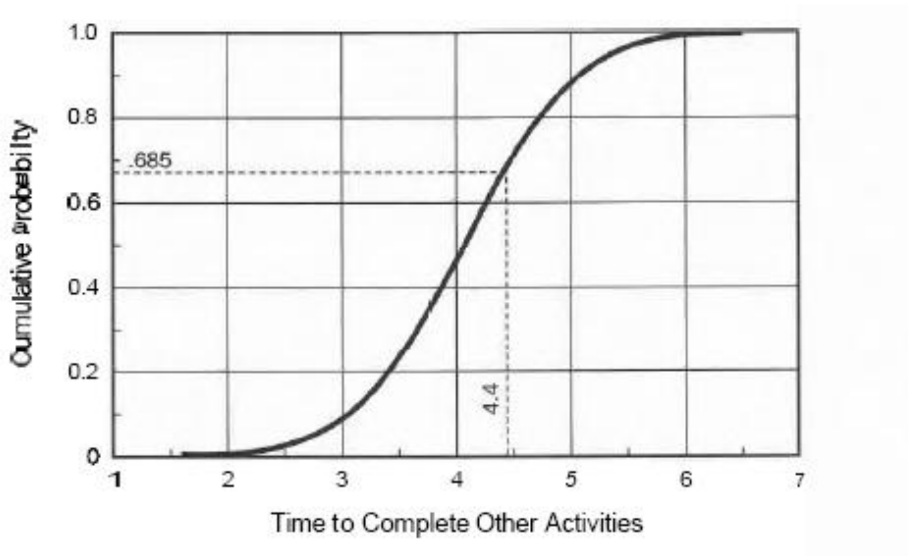

Figure 2.7: Cumulative Probability Distribution

Chapter 3

METHODOLOGY

3.1 INTRODUCTION

It is an empirical study and reports the findings of the questionnaire survey and interviews of key participants of bridge construction projects and follows with a case study of a project to further investigate the use of Monte Carlo simulations. The research was carried out by the following systematic method, as indicated in Figure 3.1.

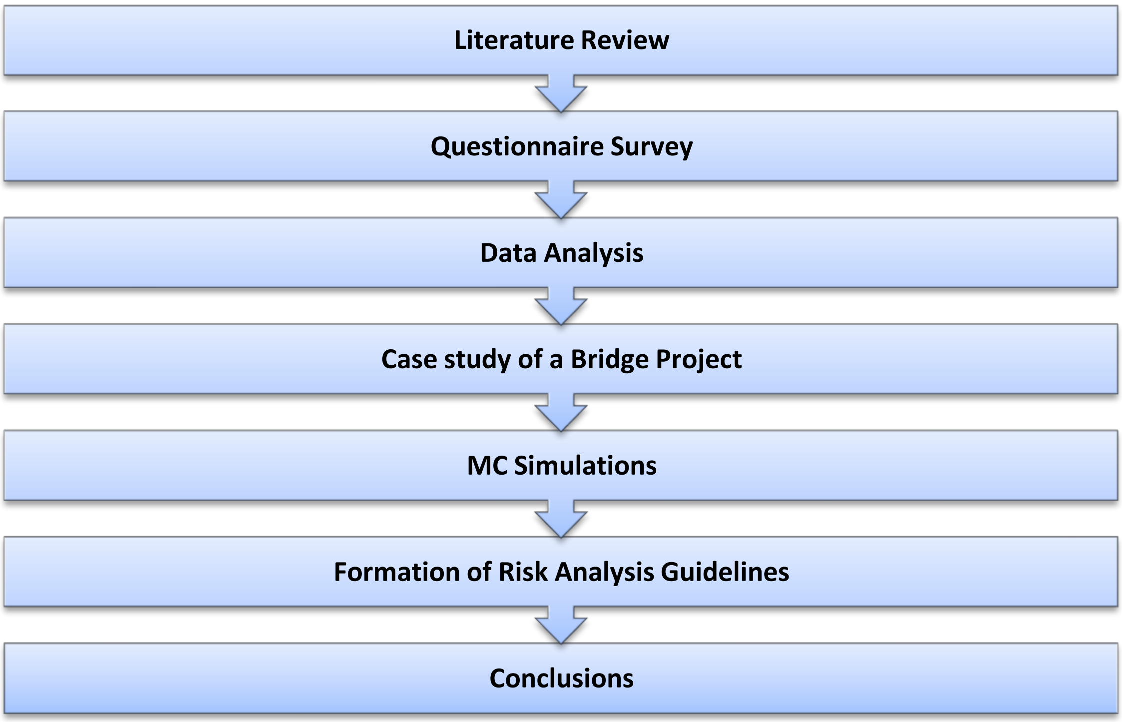

Figure 3.1: Flowchart of Research Method

3.2 QUESTIONNAIRE SURVEY

A questionnaire was developed keeping in view the important research work done by (Masood and Choudhry 2010), (Ahmed et al., 2009) and (Farooqui et al., 2007) to extract risk factors more applicable to Pakistani Construction Industry. The questionnaire was divided into two parts, first part included questions about respondent's name, name of the company, years of experience. Second part consisted of a total of 37 risk factors divided into seven categories (Appendix 1). Among the 37 items, 9 were adopted from Ahmed et al. (2009), 4 were adopted from Masood and Choudhry (2010), 4 from Farooqui et al. (2007), 3 from Choudhry and Iqbal (2012), 6 items were incorporated from the feedback obtained in the pilot survey, while the remainder 11 were developed by the researchers. Before the questionnaire survey begun, a pilot test was carried out, which included a panel of three professionals with more than 20 years of work experience in the construction industry. The respondents were requested to rate each risk factor based on its importance of impact on bridge project performance. The respondents were advised to rate the risk on a likert scale from 1 to 5. The respondents of the questionnaire were identified with the intent of obtaining accurate information related to bridge projects. This included the engineers and managers working on various bridge projects throughout Pakistan. The respondents were contacted through e-mails, fax and by personal interaction. A total of 100 questionnaires were distributed, an appreciable (77% response rate) 77 questionnaires were returned out of which 69 were usable for data analysis. The sample included 35% participants from public sector owners, 10% from private owners, 43% from consultants and 12% from contractors. It is pertinent to mention here that majority of bridge construction projects are owned by public sector because of their complex nature and involves a mammoth of finances, which the private sector is hesitant to invest. The low response of contractors is an alarm, depicting their lack of awareness and interest towards research and development. To ensure survey validation, each participant involved in the survey had an experience of working on bridge construction projects. The participants of the survey ranged from project directors, general managers, project managers and specialist engineers. Majority of the participants had acquired a bachelor's degree in civil engineering. The average experience of surveyed participants in number of years is approximately 16. From literature review a questionnaire was chosen as the principle survey method. Figure 3.2 depicts the ratio of the respondents that participated in the questionnaire with respect to their relative organization role e.g. contractor, consultant and client etc.

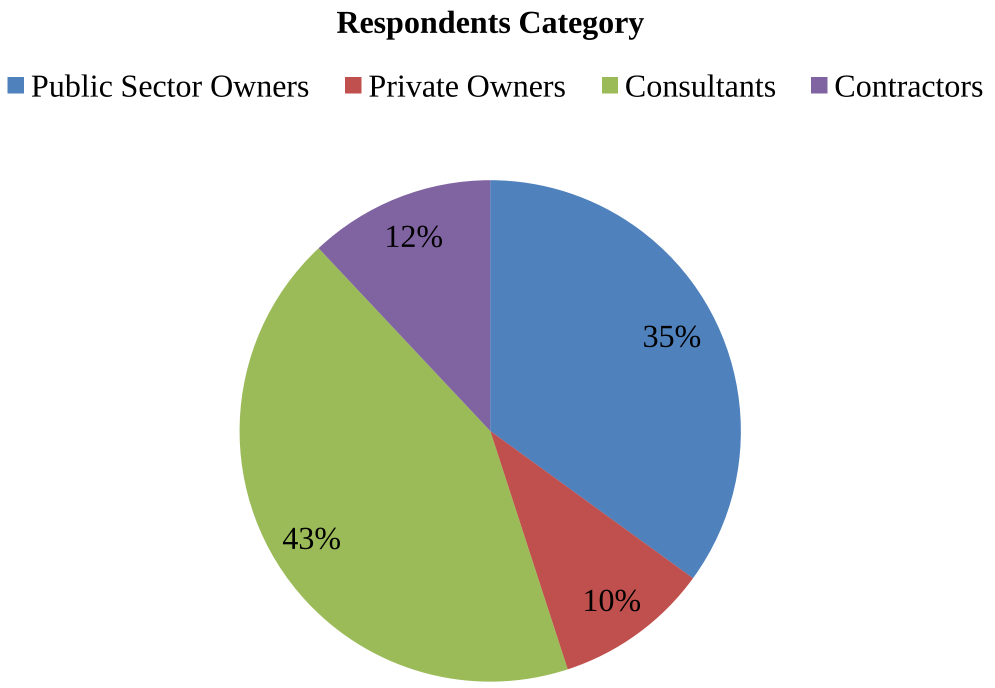

Figure 3.2: Categories of Respondents of Questionnaire Survey

3.3 SELECTION OF CASE STUDY PROJECT

The selected bridge project is constructed to facilitate an expressway connecting a highway with a housing society. The project is located in Islamabad, the capital of Pakistan. The bridge has following salient features: a) To be constructed over a river with an annual peak discharge of 11170 cusecs, b) total length of bridge 544.67 ft, c) 4 spans, d) 56 piles of diameter 2.5 ft and depth of abutment piles 50 feet, depth of pier piles 30 feet, e) 12 pile caps, f) 2 abutments, g) 4 abutment walls, h) 12 piers, six each of 36 feet, and 44 feet respectively, i) 6 transoms, j) 24 precast girders 12 each of lengths 127.66 and 144.66 ft respectively, k) 47 feet width of each deck slab, l) 12 feet length of approach slab on each side and, m) length of asphalt 545 ft and guard rails on both sides. The bridge is designed for 6 lanes of traffic.

The case study is used to extract important data to evaluate the effect of risks on project cost and time. The data is used to compare the computational result of Monte Carlo Simulation with the actual scenario; subsequently it forms the basis for the risk analysis to be performed on a project. These results are then used to formulate the risk analysis guidelines.

3.4 DATA ANALYSIS TECHNIQUE

Statistical Package for Social Science (SPSS-17) was used to analyze collected data. The study follows the level of significance i.e. 0.05 with, 0.01 being highly significant. Following statistical techniques were used to analyze the data:-

3.4.1 Preliminary Analysis

To ensure suitability for conducting factor analysis, this study used the Kaiser-Mayer-Olkin (KMO) test and Bartlett's test of sphericity. The KMO test measures the adequacy of a sample in terms of the distribution of values for the execution of factor analysis. The acceptable values should be greater than 0.5. Bartlett's test of sphericity determines if the correlation matrix is an identity matrix, if there exists an identity matrix, factor analysis meaningless (Geourge, 1999 Field, 200 Ghosh and Jintanapakanont, 2004).

3.4.2 Internal Consistency Analysis

To ensure the reliability of each factor, Cronbach's coefficient alpha (α) was used to test the internal consistency among the items included in each factor (Carmines and Zeller, 1979). (Nunnally, 1978) has recommended that a minimum of 0.7 is sufficient. Factor reliability was measured by calculating Cronbach's α for all factors (Ghosh and Jintanapakanont, 2004).

3.4.3 Relative Importance Index (RII) and Ranking

For this type of data, the mean and standard deviation of each factor are not suitable and to determine the overall ranking because they do not reflect any relationship between the factors (Chan and Kumaraswamy, 1997). Instead, the weighted average for each factor was calculated and then divided by the upper scale of the measurement. This results in an importance index (Shash 1993 Ghosh and Jintanapakanont, 2004).

3.4.4 Pearson's Product-Moment Correlation

The Pearson Product-Moment Correlation Coefficient r (Rho) or correlation coefficient for short is a measure of the degree of linear relationship between two variables. The computation of the correlation coefficient is most easily accomplished with the aid of a statistical calculator. The correlation coefficient may take on any value between plus and minus one. The sign of the correlation coefficient (+,-) defines the direction of the relationship, either positive or negative. A positive correlation coefficient means that as the value of one variable increases, the value of the other variable increase; as one decreases the other decrease. A negative correlation coefficient indicates that as one variable increases, the other decreases, and vice-versa.

Taking the absolute value of the correlation coefficient measures the strength of the relationship. A correlation coefficient of r=.50 indicates a stronger degree of linear relationship than one of r=.40. Thus a correlation coefficient of zero (r=0.0) indicates the absence of a linear relationship and correlation coefficients of r=+1.0 and r=-1.0 indicate a perfect linear relationship.

3.5 SUMMARY

This chapter describes the framework of the research study to be conducted on the subject. A questionnaire will be used as a primary survey method. Data obtained from the survey will be tested statistically. The statistical tests applied to the data are mentioned above. Further to this, a case study is used to analyze the affects of risks on project cost and schedule. This evaluation of data serves plateful for the compilation of risk analysis guidelines.

Chapter 4

DATA ANALYSIS

4.1 INTRODUCTION

Statistical Package for Social Science (SPSS-17) is flexible and comprehensive statistical tool which can take data from different type of files and uses them to perform intricate statistical analysis including charts, trends, and tabulated reports. SPSS helps in calculations and produces results, the subsequent part i.e. drawing quality inferences from these results, depends upon the degree of knowledge and expertise of the researcher about statistics as a subject. The data was entered in SPSS progressively as all 69 questionnaires were received and were checked for correctness and completeness.

4.2 PRELIMINARY ANALYSIS

The result of the KMO test was 0.689 which is greater than 0.5 and is acceptable to continue factor analysis on the data available. Bartlett's test of sphericity was high at 1626.489 (associated with a probability value of 0.00). Table 4.1 summarizes the output of both these test.

Table 4.1: Preliminary Analysis

KMO and Bartlett's Test		Value
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.689
Bartlett's Test of Sphericity	Approx. Chi-Square	1626.489
	Sig.	.000

4.3 INTERNAL CONSISTENCY ANALYSIS

The results of factor analysis showed that the 37 sub factors within seven categories had the cronbach's (α) values ranged from 0.921 to 0.912 (Table 4.2 and 4.3). These values are greater than 0.8 which means all the variables are reliable, deleting any of the variable will not significantly increase the cronbach's (α). Overall (α) is 0.917.

Table 4.2: Internal Consistency Analysis

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.917	.915	37

Table 4.3: Cronbach's Alpha for Risk Factors

Risk Factor	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
F1	115.2029	451.194	.358	.646	.916
F2	114.9130	466.639	.162	.543	.918
F3	114.6377	465.117	.159	.486	.918
F4	115.3043	476.715	-.095	.825	.921
F5	115.5652	461.073	.223	.822	.918
F6	114.1739	464.969	.184	.542	.918
F7	115.3768	453.091	.355	.504	.916
F8	115.8406	452.960	.499	.775	.915
F9	115.6232	460.297	.259	.737	.917
F10	115.1304	456.086	.346	.800	.916
F11	115.2754	445.820	.547	.771	.914
F12	115.4058	455.009	.281	.617	.918
F13	114.7681	456.328	.298	.733	.917
F14	115.8696	442.497	.516	.873	.914
F15	115.7536	445.777	.529	.852	.914
F16	115.6957	439.891	.565	.807	.914
F17	114.7681	446.122	.547	.836	.914
F18	115.0000	449.441	.480	.811	.915
F19	115.3913	446.359	.571	.812	.914
F20	114.7536	450.924	.463	.711	.915
F21	115.9565	442.013	.611	.850	.913
F22	115.3623	448.970	.513	.719	.914
F23	114.7536	464.012	.192	.641	.918
F24	114.8696	437.527	.663	.783	.912

Risk Factor	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
F25	114.9710	443.793	.618	.819	.913
F26	115.5797	442.806	.588	.810	.913
F27	115.2754	450.202	.522	.627	.914
F28	115.7971	439.429	.581	.815	.913
F29	115.3913	441.271	.582	.856	.913
F30	115.2464	439.718	.591	.805	.913
F31	115.6812	441.897	.696	.836	.912
F32	115.7101	440.591	.577	.759	.913
F33	115.0000	439.559	.620	.748	.913
F34	115.0000	436.176	.631	.887	.913
F35	115.6812	436.838	.694	.896	.912
F36	115.1159	445.692	.515	.807	.914
F37	114.8551	445.243	.450	.632	.915

4.4 IMPORTANCE OF RISKS

Respondents were required to provide responses of the importance of 37 risks affecting construction industry on likert scale 1-5, where 1 represented "insignificant" and 5 represented "extraordinary". The participants within the project organization provided numerical scores that expressed their opinions on the level of importance of each factor and its effect on meeting the cost and time of the project. The relative importance of each risk factor was calculated using the following equation:

$$\text{Relative Importance Index (RII)} = \sum (aX) * 100/5 \qquad \text{(Equation 1)}$$

Where a is the constant that expresses the weighting given to each response, ranging from 1 (insignificant) to 5 (extraordinary); and $X = n/N$, where n is the frequency of the responses; and N is the total number of responses. The results of the relative importance index in descending order is financial risks (RII = 69.95), external risks (RII = 66.67), design risks (RII = 66.28), management risks (RII = 65.17), construction risks (RII = 62.72), contractual risks (RII = 59.42), health &

safety risks (RII = 53.82). The results are presented in Table 4.5. In order to identify the criticality of the risk factors, a risk rating matrix is purposed based on the questionnaire survey and the likert scale, as shown in Table 4.4.

Table 4.4: Criticality of Risks with RII values

Criticality of Risk Factor	Relative Importance Index
Extraordinary	81-100
Major	61-80
Moderate	41-60
Minor	21-40
Insignificant	0-20

Table 4.5: RII of risk factor categories in descending order

Risk Category	Relative Importance Index	Criticality
Financial Risks	69.95	Major
External Risks	66.67	Major
Design Risks	66.28	Major
Management Risks	65.17	Major
Construction Risks	62.72	Major
Contractual Risks	59.42	Moderate
Health & Safety Risks	53.82	Moderate

Factor wise relative importance index was also computed, results displayed in Table 4.6. It is evident from the table that financial risks are the most important while affecting the cost and time of the project. The top fifteen risk factors in descending order of importance are unavailability of funds (RII = 85.80), financial failure of contractor (RII = 76.52), poor site management & supervision (RII = 74.20), inadequate site investigation (RII = 73.91), inadequate project planning (RII = 73.91), construction delays (RII = 73.62), unavailability of land / right of way not clear (RII = 72.17), defective work / quality issue (RII = 71.88), financial delays (RII = 71.01), insufficient technology (RII = 69.86), insufficient engineers & specialist (RII = 69.28), delay in approvals from regulatory bodies (RII = 69.28), political instability (RII = 69.28), unstable government policies (RII = 66.96), Unrealistic schedules & cost-estimates (RII = 66.67).

Table 4.6: RII of risk factors in descending order

Rank	Risk Factor	Relative Importance Index	Risk Category	Criticality of Risk Factor
1	Unavailability of funds	85.80	Financial & Economic risk	Extraordinary
2	Financial failure of contractor	76.52	Financial & Economic risk	Major
3	Poor site management & supervision	74.20	Management risk	Major
4	Inadequate site investigation	73.91	Design risk	Major
4	Inadequate project planning	73.91	Management risk	Major
6	Construction delays	73.62	Construction risk	Major
7	Unavailability of Land / ROW not clear	72.17	External risk	Major
8	Defective work / Quality issue	71.88	Construction risk	Major
9	Financial delays	71.01	Financial & Economic risk	Major
10	Insufficient technology	69.86	Construction risk	Major
11	Insufficient engineers & specialist	69.28	Management risk	Major
11	Delay in approval from regulatory bodies	69.28	External risk	Major
11	Political instability	69.28	External risk	Major
14	Unstable government policies	66.96	External risk	Major
15	Unrealistic schedules & cost-estimates	66.67	Contractual risk	Major
16	Economic disaster	65.22	Financial & Economic risk	Major
17	Unexpected site conditions (dewatering/rock)	64.35	Construction risk	Major
18	Design changes	63.77	Design risk	Major
18	Material shortage	63.77	Construction risk	Major

Rank	Risk Factor	Relative Importance Index	Risk Category	Criticality of Risk Factor
20	Hike in material prices	63.19	Financial & Economic risk	Major
21	Subcontractor failure	62.03	Management risk	Major
22	Change in project scope / Change orders	61.74	Contractual risk	Major
23	Lack of co-ordination	61.45	Management risk	Major
23	Scope of work not clear	61.45	Construction risk	Major
25	Design not complete	61.16	Design risk	Major
26	Inflation	57.97	Financial & Economic risk	Moderate
27	Labor productivity	57.68	Construction risk	Moderate
28	Disputes / Claims	56.81	Contractual risk	Moderate
29	Unexpected weather (rain/windstorms)	55.65	Construction risk	Moderate
29	Third party delays	55.65	External risk	Moderate
31	Fatality	55.36	Health & safety risk	Moderate
32	Work interruptions / Lack of space	55.07	Construction risk	Moderate
33	Equipment and Property damage	54.20	Health & safety risk	Moderate
34	Over inspections / audits	53.33	Construction risk	Moderate
35	Contractual anomalies	52.46	Contractual risk	Moderate
36	Accidents	51.88	Health & safety risk	Moderate
37	Strikes & Theft	50.14	Management risk	Moderate

4.5 PEARSON'S CORRELATION

The Pearson's correlation amongst the risk factor categories is displayed in Table 4.7. The highest correlation is among the construction and management risks 0.756 at significance level 0.01. Another important correlation is 0.605 at significance level 0.01 among construction and external risks. External risks tend to impact cost and time more than the construction risks as shown in Table 4.5; they are in fact the second most important risk factor category. A positive correlation amongst health & safety risks and construction 0.459 at significance level 0.01 is depicting that, as the construction risks increase, so does the physical hazards. The health & safety risks are positively correlated to contractual risks 0.428 at significance level 0.01.

Table 4.7: Correlations among the Risk Factors

Risk Factor Category	Financial	Contractual	Design	Safety	Management	Construction	External
Financial	1						
Contractual	.442**	1					
Design	.306*	.374**	1				
Safety	.098	.428**	.341**	1			
Management	.174	.445**	.374**	.366**	1		
Construction	.113	.380**	.250*	.459**	.756**	1	
External	.162	.290*	.399**	.373**	.430**	.605**	1

**. Correlation is significant at the 0.01 level

*. Correlation is significant at the 0.05 level

4.6 CASE STUDY OF A BRIDGE PROJECT

For the purpose of this research, a work schedule of the project was developed and saved as a baseline. Similarly a base cost-estimate of the project was prepared. The estimate was prepared in a manner that each activity could be assigned a cost. To remove the bias of missing the project over-head costs, the estimate of each activity included the sum of material costs, manpower costs, equipment costs and overhead costs.

The risks identified through the questionnaire survey were then loaded into the schedule to quantify the impact of these risks on project schedule and cost. For the purpose of risk analysis, Primavera Pertmaster V8 was used. The inputs of Pertmaster for risk register are a) risk ID number, b) threat or opportunity (T/O), c) risk description, d) probability of occurrence, e) effect of this risk on activity, f) type of risk i.e. cost, time or performance, g) distribution type i.e. triangular, uniform, etc., h) correlation with other risk factors. The sample risk register shown below was created for the complete project. Inputs required by software, like probability, impact of risk on activity, risk correlation, etc, were entered with consultation of the same panel involved in pilot survey of the questionnaire (Figure 4.1 and Figure 4.2).

The work schedule which is loaded with costs and risks is subjected to risk analysis. The risk analysis function performed by the Pertmaster V8 is based on MC simulation. MC simulation is perhaps the most popular of the various management science techniques. The simple, elegant method provides a means to solve equations with probability distributions (Schuyler, 2001). MC simulation is a technique that uses random samples of the independent variables to obtain solutions of problems. Simple random number sampling and Latin hypercube sampling are among the possible many sampling techniques that can be used with Monte Carlo simulations (Lian and Yen, 2003). Further to embellish the study project it was decided that 1000 iterations are to be performed by the software (Figure 4.3 and Figure 4.4).

The cumulative probability distribution of project cost, finish date and duration were computed through MC simulations. Extract of project cost is shown in Figure 4.5. The cumulative probability distribution of project cost and duration is shown in Figure 4.6. Table 4.8 gives a summary of the risk impact on project cost and duration. The probability to finish project within cost is less than 1% and within time is 4%. Terms P80 and P100 represent the probability, 80% and 100% respectively. The arrows in Figure 4.6 are representing the project completion with 80% and 100% probability.

Table 4.9, 4.10, 4.11 and 4.12 are drawing the comparison of simulation results with actual data of the case study project. The time of observation for the project was from November 2009 to March 2011, therefore the comparison was drawn with the actual completion cost and time of each activity.

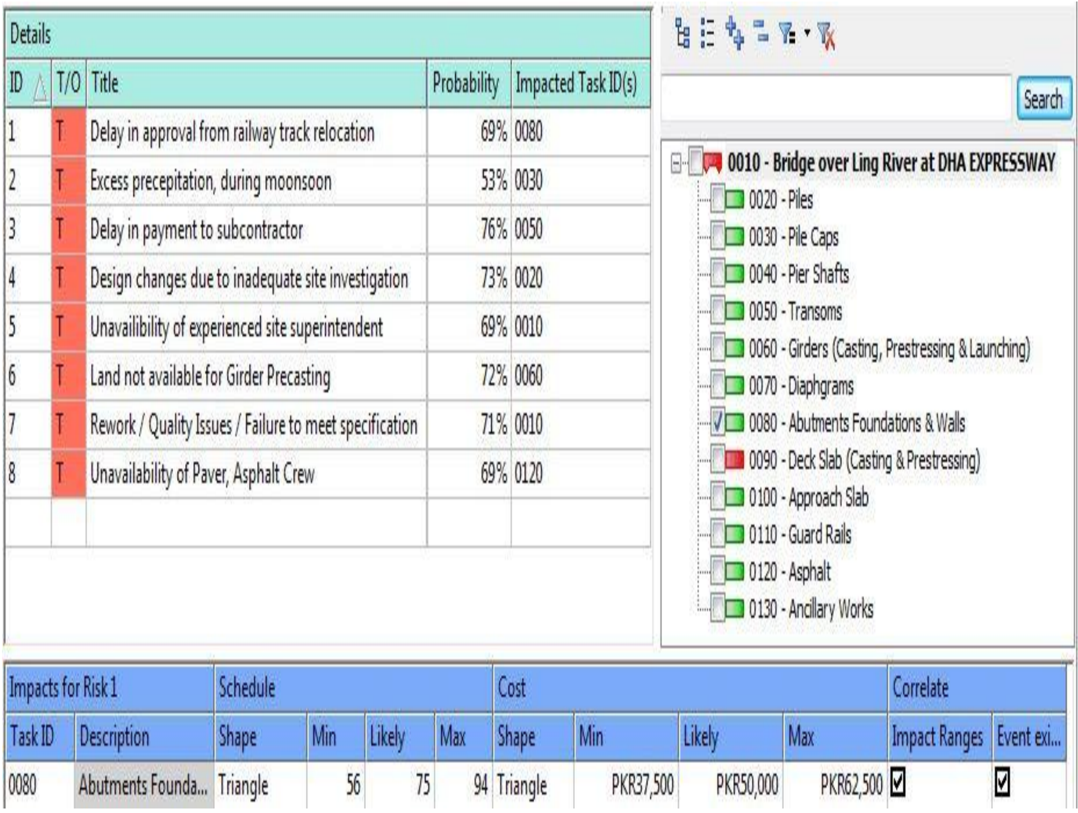

Figure 4.1: Risk Register of Case Study Project

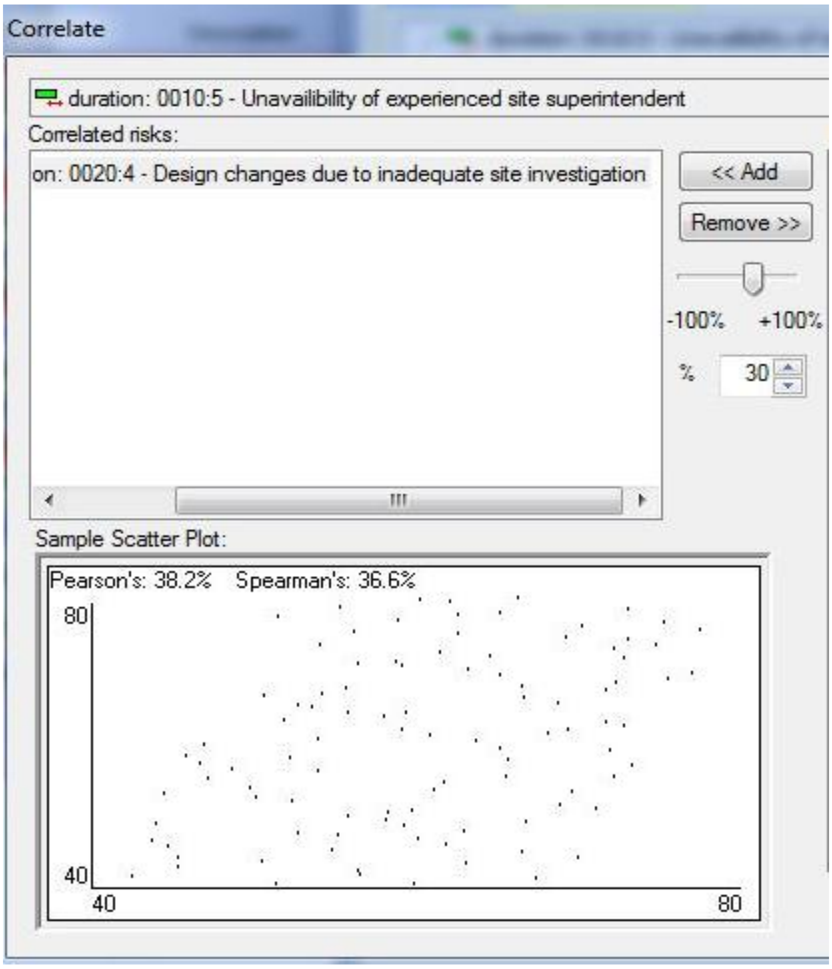

Figure 4.2: Risk Correlation of Case Study Project

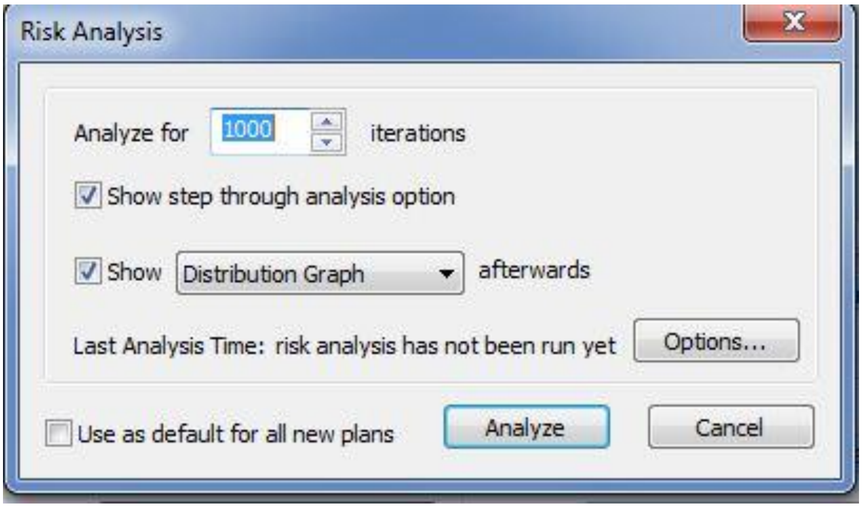

Figure 4.3: Risk Analysis in Pertmaster

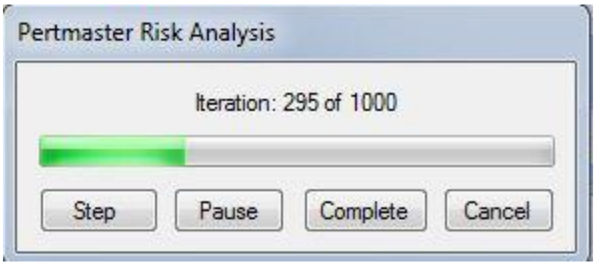

Figure 4.4: Iterations

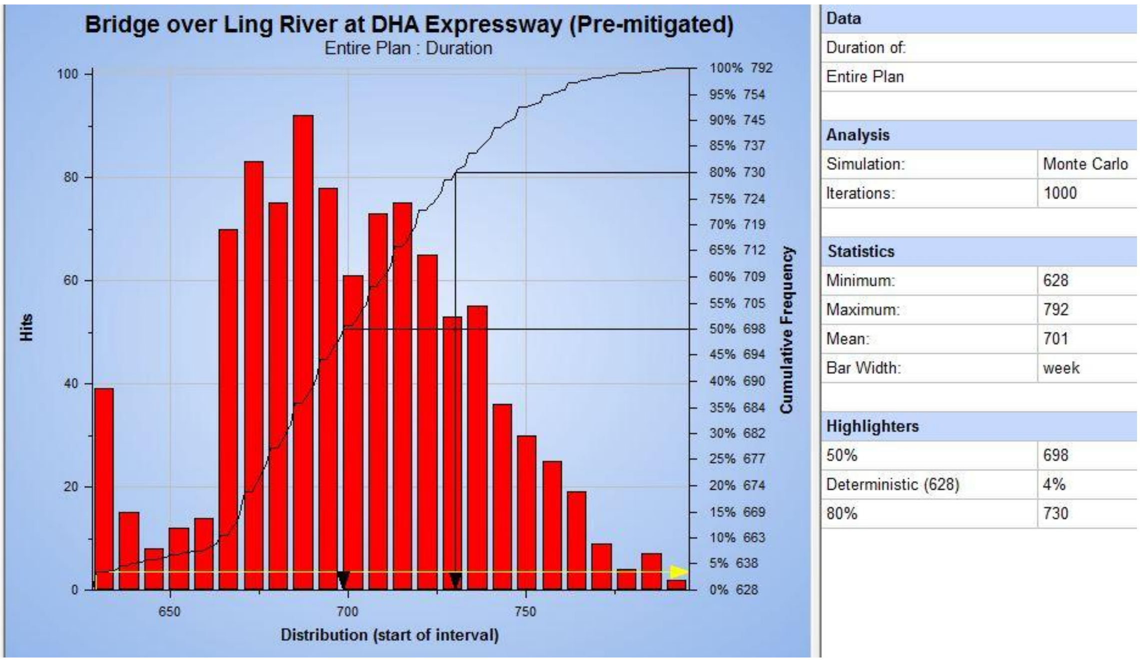

Figure 4.5: MC Simulation results and Impact of risks on project schedule

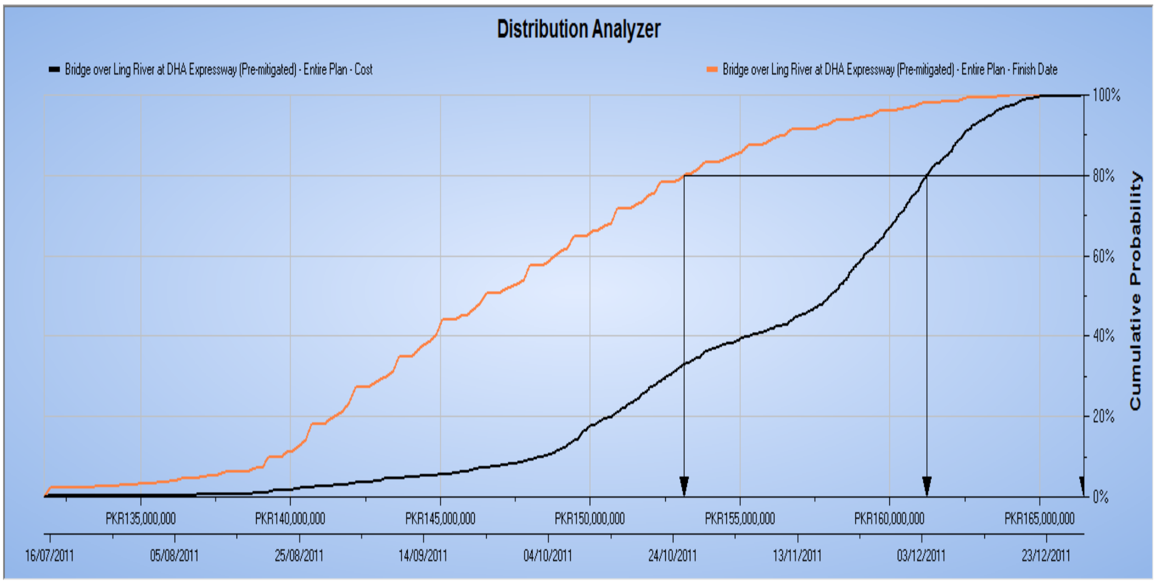

Figure 4.6: Impact of risk on Project time and cost

Table 4.8: MC Simulation Results of the Case Study Project

Description	Deterministic Value	Deterministic Probability	Mean	P80	P100
Cost (PKR)	129,221,836	<1%	156,006,383	164,710,654	175,557,769
Duration (Days)	628	4%	701	730	792
Finish Date	15/07/2011	4%	25/09/2011	25/10/2011	26/12/2011

Table 4.9: Comparison of MC Simulation Results with Actual (Start Date)

Activity	Base Line Start	P80 Start	P100 Start	Actual Start
Piles	26/10/2009	26/10/2009	26/10/2009	26/10/2009
Pile Cap	18/2/2010	7/4/2010	18/4/2010	4/6/2010
Pier Shaft	14/3/2010	4/7/2010	3/8/2010	10/6/2010
Transoms	2/5/2010	23/8/2010	21/9/2010	1/1/2011
Girders	6/3/2010	21/5/2010	3/7/2010	
Diaphragm	16/9/2010	26/12/2010	27/2/2011	
Abutments	25/2/2010	14/4/2010	25/4/2010	
Deck Slab	6/10/2010	15/1/2011	19/3/2011	
Guard Rail	5/12/2010	16/3/2011	18/5/2011	
Electrical Works	20/12/2010	31/3/2011	2/6/2011	
Asphalt	27/6/2011	4/10/2011	6/12/2011	

Table 4.10: Comparison of MC Simulation Results with Actual (Finish Date)

Activity	Base Line Finish	P80 Finish	P100 Finish	Actual Finish
Piles	17/2/2010	6/4/2010	17/04/2010	14/4/2010
Pile Cap	13/5/2010	3/9/2010	2/10/2010	13/9/2010
Pier Shaft	19/6/2010	18/11/2010	27/12/2010	27/10/2010
Transoms	21/8/2010	28/01/2011	12/3/2011	31/3/2011
Girders	12/11/2010	21/02/2011	25/04/2011	
Diaphragm	12/12/2010	28/03/2011	25/05/2011	
Abutments	13/9/2010	17/01/2011	8/2/2011	
Deck Slab	14/2/2011	28/05/2011	17/09/2011	
Guard Rail	25/6/2011	3/10/2011	5/12/2011	
Electrical Works	14/6/2011	22/09/2011	24/11/2011	
Asphalt	15/7/2011	25/10/2011	26/12/2011	

Table 4.11: Comparison of Durations

Activity	Baseline Duration	P80 Duration	P100 Duration	Actual Duration
Piles	114	162	173	170
Pile Cap	84	149	167	101
Pier Shaft	97	137	146	139
Transoms	111	158	172	89
Girders	251	276	296	
Diaphragm	87	92	97	
Abutments	200	278	289	
Deck Slab	131	133	182	
Guard Rail	202	202	211	
Electrical Works	176	176	185	
Asphalt	18	21	22	

Table 4.12: Comparison of Costs

Activity	Baseline Cost	P80 Cost	P100 Cost	Actual Cost
Project	129,221,836	161,149,586	165,945,109	72,840,547
Up to Transoms	37,198,110	69,787,628	76,047,911	72,840,547
Piles	12,010,943	23,610,037	24,903,230	23,519,573
Pile Cap	9,635,810	17,950,572	19,539,369	18,868,638
Pier Shaft	10,380,331	19,673,635	21,374,974	20,326,544
Transoms	5,171,026	8,553,384	10,230,338	10,125,792
Girders	47,749,149	48,672,759	49,247,929	
Diaphragm	2,015,959	2,309,237	3,010,231	
Abutments	3,790,841	5,473,253	5,790,028	
Deck Slab	20,934,974	20,934,974	21,911,994	
Guard Rail	5,666,186	5,666,186	5,764,904	
Electrical Works	8,820,857	8,820,857	9,776,048	
Asphalt	3,045,760	3,045,760	4,008,724	

4.7 SUMMARY

The chapter discussed the complete analysis process and results are presented. It presents the risk ranking on the basis of the survey data analyzed and found the criticality of risk factors on project cost and time. It has also summarized the case study with the actual situation compared to computational results performed by the Monte Carlo simulation method.

Chapter 5

DISCUSSION

5.1 INTRODUCTION

The risk factors administered through the questionnaire survey and then analyzed are explained as follows:

5.1.1 Financial & Economic Risks

It is overall ranked first (RII = 69.95) amongst the seven risk factor categories. It consisted of six risk factors, unavailability of funds (RII = 85.80) with a very high importance index was also ranked first among all the 37 identified risk factors. Other risk factors included financial failure of contractor (RII = 76.52) ranked second. Financial delays (RII = 71.01) ranked ninth. Economic disaster (RII = 65.22), hike in material prices (RII = 63.19), inflation (RII = 57.97). It is notable that three of the six risk factors ranked in top ten important risk factors in terms of importance index. Further to that five of the risk factors have an RII greater than 60, which indicates that these risks are significant while meeting the project cost and time targets. Interest rates are external factors mostly governed by policies of State Bank of Pakistan. The policy / discount rate of State Bank of Pakistan is shown in Table 5.1 and reveals that it was as high as 15 percent on Nov 08 and was as low as 9.5 percent on 22 Jul 06, which is presently at 14 percent.

There is an increase of 150 basis points in 2010 mainly due to high inflation and government borrowings. As per State Bank of Pakistan (2011), Karachi interbank offer rate (KIBOR) which is a bench mark for corporate lending, has been steadily following the rise in the SBP policy / discount rate. Accordingly, the six month KIBOR had increased by 146 basis points to 13.9 percent till 28 Jan 11, ever since the monetary policy was announced on 29 Jul 10. Most of the corporate loan agreements have floating rates; it means automatic adjustment of interest rate with KIBOR, which may affect project cash flows and capital supply. Changes in cash flows and capital supply may affect the project negatively in many ways including but not limited to delays, cost overruns, poor quality and at times abandonment of the project. Contractors relying on corporate lending to bridge financial gaps become more vulnerable, especially when partial payments on performed work may be delayed by the client due to any reason. Interviews revealed that contractors are concerned about ongoing projects in public sector due to Government's decision, to reduce funding in the backdrop of recent unprecedented floods in mid 2010.

The financial factors assume leading position in the listing of risks for the reason that if not addressed timely, they have the potential to choke the project completely. A financially healthy project is likely to meet its intended objectives more aggressively (Iqbal, 2011). Survey revealed that inflation and price hike is the major concern followed by rupee exchange rate and taxes. The principle measure of price variation at retail level is Consumer Price Index (CPI) and generally represents inflation rate in the country. Figure 5.1 shows the month wise year-on-year CPI inflation for the years of 2008, 09 and 10. It may be observed that, it is mostly in double digits except for the month of October 09 and is considered on the higher side. According to State Bank of Pakistan (2011), the projected average CPI inflation for current financial year falls in the range of 15-16 percent (revised) and in all probability 2012 is again likely to witness double digit CPI inflation. This rising trend may only be arrested by reduction in both government borrowings and fiscal deficit. Inflation is underlying cause of upward movement of State Bank of Pakistan policy rate and prices of major inputs to construction industry i.e. cement, steel and oil. This amplifies that the fundamental reason of the risks of financial factors is the economic factors and that too mainly inflation. Table 5.2 shows prices of major inputs to construction industry from Jan 2009 to Jul 2010.

A closer look to price fluctuation reveals that in a span of 12 months from Apr 09 to Apr 10, the price of cement is reduced by 23.07 percent mainly due to locally available raw material and less demand, the price of steel increased by 24.03 percent, the price of petrol increased by 30.17 percent and the price of diesel increased by 34.36 percent. The cement production stands at 22.8 million tons in 2009-10 against the installed capacity of 44.00 million tons indicating 51.8% capacity utilization State Bank of Pakistan (2010). According to All Pakistan Cement Manufacturers Association (APCMA), the cement sales dropped by 10.48 percent in first eight months of current financial year (Jul 10 – Feb 11) as compared to sales in previous year during the same period. It is mainly due to reason that the purchasing power of the consumer is eroded by combined effect of low economic activity and inflationary pressures. The devaluation of rupee as presented in Table 5.3, against major currencies of the world is another area of concern as it increases import bill of construction machinery, chemicals, Oil and raw material for steel, there by escalating the cost of construction. In a span of seven years (2003-10) rupee was devalued by 45.14 percent (83.56 – 57.57 = Rs. 25.99) against US dollar, and by 74.06 percent (119.44 – 68.62 = Rs. 50.82) against Euro, which is unprecedented if compared to other regional currencies. Pakistani currency even depreciated against regional currencies like Indian rupee and Bangladesh Taka in 2001-10. It has been devalued against Indian rupee by 40.16 percent (1.78 – 1.27 = Rs. 00.51) and against Bangladesh Taka by 11.11 percent (1.20 – 1.08 = Rs. 00.12) since 2001. As observed by Ministry of Finance (2010), the problem of inflation was compounded by devaluation of rupee which also posed a serious threat to the economy and society at large during 2008- 09. The World Bank (2011) has downgraded Pakistan's ranking from 75th position in 2010 to 83rd position in 2011 in ease of doing business in its annual report of "Doing Business 2011" (Iqbal, 2011).

5.1.2 External Risks

This category has been overall ranked second (RII = 66.67) and it consisted of five risk factors. The most important risk factor in this category, unavailability of land or right of way not available (RII = 72.17) ranked as the seventh important risk factor overall. Delay in approvals from regulatory bodies (RII = 69.28), political instability (RII = 69.28), unstable government policies (RII = 66.96) were the other three important risk factors in this category. The importance of this category can be judged by the fact that four out of five of these risk factors ranked within the top fifteen risk factors. Third party delays (RII = 55.65) seemed to be a risk within this category but with a relative low importance to affect cost and time of a bridge project.

Prevailing situation and the survey results show that how important are the external risks for bridge projects which is an alarming situation. Survey revealed that law and order situation especially in the background of war on terror is foremost concern of all groups. There is a general perception among the respondents that the current law and order situation is a reaction to war on terror, which has both human and monetary dimensions and is eroding whatever limited fiscal space is available to the country. Contractors and consultants interviewed, were reluctant to work in federal administered tribal areas (FATA) and Baluchistan, which comprises of more than half of Pakistan's geographical area, mainly due to risks involve to human lives and business.

This may be judged from the fact that according to State Bank of Pakistan (2010) a total of 8,141 terror related incidents have occurred in Pakistan in a span of eight years (2002-10), which resulted in 8,875 deaths and as much as 20,675 injuries to the people. Figure 5.2 shows year wise human losses and shows an intensification of fatalities in 2008-09. The effects of the war on terror and arising terror activities in reaction have been colossal especially on economic front. As per State Bank of Pakistan (2010) the country has suffered a cumulative (direct and indirect) loss of US$ 43.2 billion (Table 5.4) in the areas of investment, GDP growth, exports, physical infrastructure, budgetary resources, public sector development spending, exchange rates, inflation, rehabilitation of internally displaced people, security and capital flight. Growth and investment have slowed down due to negative effects of the war on terror. Table 5.5 shows changes in foreign direct investment (FDI), large scale manufacturing (LSM), exports and real GDP growth for last nine financial years. The real GDP in 2008-09 was 1.2 percent with large scale manufacturing shrinking to -8.2 percent. It may be observed that, average GDP growth was 6.6 percent in 2004-08 and large scale manufacturing grew by average 11.9 percent in that period. The change in FY 2008-09 to five year's average is minus 5.4 percent for GDP, minus 20.1 percent for large scale manufacturing and minus 1.1 percent for exports and the same is supported by surge in human fatalities in 2008-09 (Figure 5.2). The exact impact of this factor on construction industry is difficult to calculate in the absence of reliable data, however, the construction industry is being affected in similar way as any other industry of Pakistan (Iqbal, 2011).

Table 5.1: State Bank of Pakistan (2010) Policy Rate

Period / Date	SBP Policy / Discount Rate (Percent)	Basis Points
22 Jul 06	9.5	-
1 Aug 07	10	+50
2 Feb 08	10.5	+50
23 May 08	12	+150
30 Jul 08	13	+100
13 Nov 08	15	+200
21 Apr 09	14	-100
17 Aug 09	13	-100
25 Nov 09	12.5	-50
29 Jul 10	13	+50
Sep 10	13.5	+50
Nov 10	14	+50
29 Jan 11	14	-

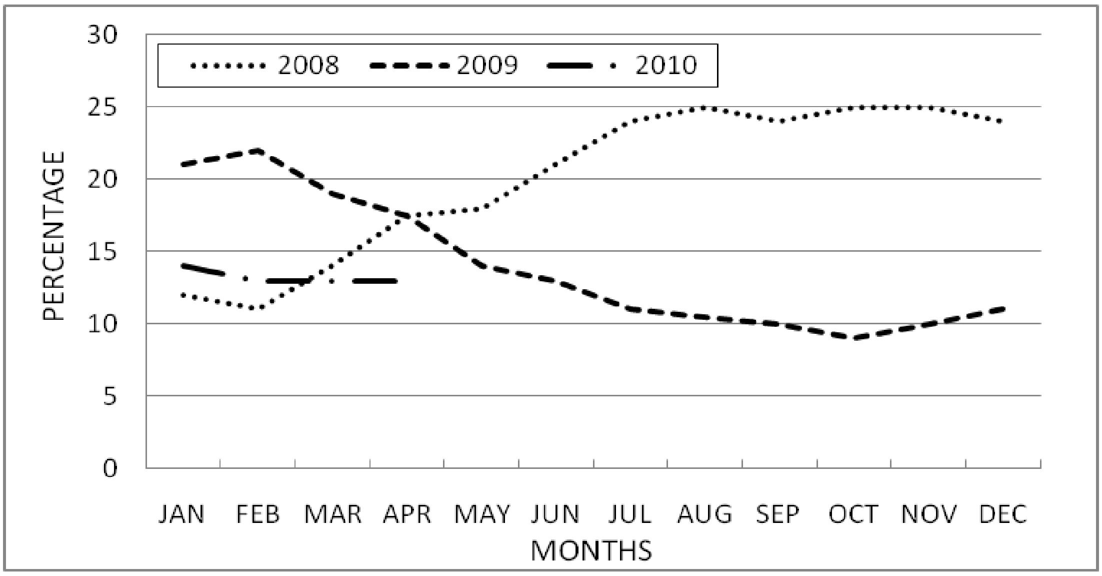

Figure 5.1: Month Wise Year-on-Year CPI Inflation (State Bank of Pakistan 2010)

Table 5.2: Prices of Construction Input Items (Federal Bureau of Statistics 2010)

Period	Cement	Steel	Petrol	Diesel
	Rs per Bag	Rs per Ton	Rs per Littre	Rs per Littre
Jan 09	380.00	53000.00	57.76	57.24
Apr 09	357.50	52000.00	57.76	57.24
Jul 09	350.00	55000.00	60.57	61.58
Oct 09	270.00	50000.00	61.74	64.90
Jan 10	255.00	57500.00	71.32	71.97
Apr 10	275.00	64500.00	75.19	76.91
Jul 10	315.00	62000.00	67.86	73.15

Table 5.3: Exchange Rate (State Bank of Pakistan 2010)

Financial Year	Average Open Market Exchange Rate (Pak Rs)			
	US Dollar	Euro	Indian Rupee	Bangladesh Taka
2001-02	61.42	54.99	1.27	1.08
2002-03	58.49	61.30	1.22	1.01
2003-04	57.57	68.62	1.26	0.98
2004-05	59.35	75.53	1.32	0.97
2005-06	59.85	72.86	1.33	0.91
2006-07	60.63	79.17	1.37	0.87
2007-08	62.54	92.17	1.54	0.90
2008-09	78.49	107.43	1.64	1.14
2009-10	83.56	119.44	1.78	1.20
8 Mar 2011	85.36	-	-	-

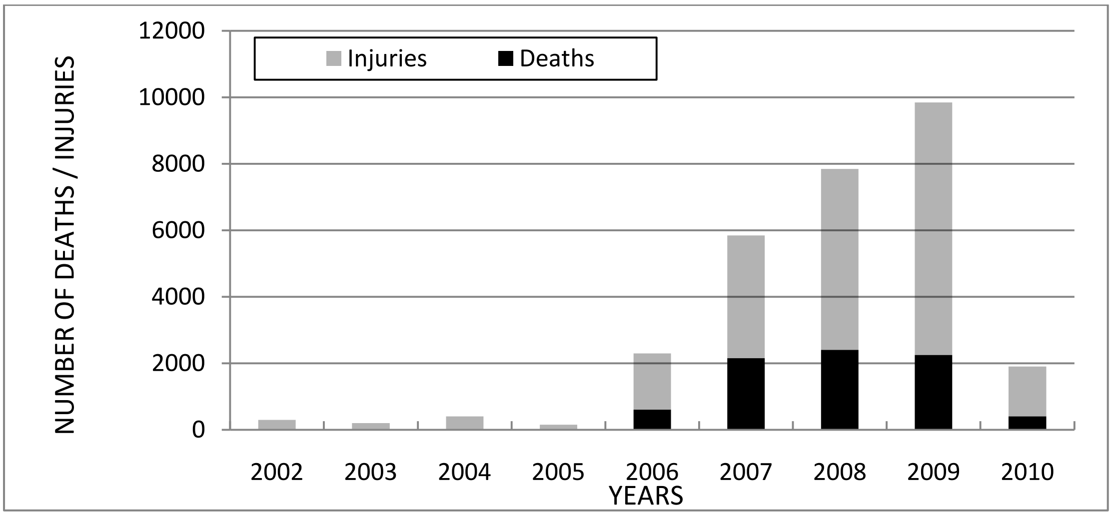

Figure 5.2: Year Wise Human losses (State Bank of Pakistan 2010)

Table 5.4: Estimated Loss to Economy (State Bank of Pakistan 2010)

Financial Year	Indirect Cost (Billion Rs)	Direct Cost (Billion Rs)	Total (Billion Rs)	Total (Billion US $)
2004-05	192	67	259	4.4
2005-06	223	78	301	5.0
2006-07	278	83	361	6.0
2007-08	376	109	485	7.7
2008-09	564	114	678	8.6
2009-10	707	262	969	11.5
Total	2340	713	3053	43.2

Table 5.5: Change in Major Economical Indicators (State Bank of Pakistan 2010)

Year	FDI (Billion US $)	LSM (Percent)	Exports (Billion US $)	GDP (Percent)
2001	0.3	10.2	9.2	2.0
2002	0.5	3.8	9.14	3.1
2003	0.8	0.4	11.1	4.7
2004	0.9	18.5	12.3	7.5
2005	1.5	18.8	14.3	9.0
2006	3.5	9.2	16.4	5.8
2007	5.1	8.8	17.0	6.8
2008	5.2	4.2	19.1	4.1
2009	3.7	-8.2	14.8	1.2
5 Years Average (2004-08)	3.3	11.9	15.8	6.6
Change (5 Years average to 2008/09)	0.5	-20	-1.1	-5.4

FDI = Foreign Direct Investment
LSM = Large Scale Manufacturing
GDP = Gross Domestic Product

5.1.3 Design Risks

The design risk category ranked as the third most important out of the identified seven categories (RII = 66.28). The component risk factors in this category were inadequate site investigation (RII = 73.91) and ranked as the fourth important risk factor out of 37. Design changes (RII = 63.77) and design not complete (RII = 61.16) were the other two significant important risk factor as a constituent to this category. The complex nature of bridge projects and its reliability on the quality of design depicts the importance of these risks.

5.1.4 Management Risks

This risk factor category ranked fourth (RII = 65.17). Management risk factors were identified as poor site management and supervision (RII = 74.20) it ranked as third most important risk factor overall. Inadequate project planning (RII = 73.91), insufficient engineers and specialist (RII = 69.28) ranked fourth and eleventh overall. Subcontractor failure (RII = 62.03), lack of coordination (RII = 61.03) were the significant factors constituent to this category. Strikes and thefts (RII = 50.14) was ranked as the least important risk factor overall. The importance of project management is emphasized by these results, with better project management a thorough response planning can be carried out to address the mentioned risk factors. It is important to note that five out of six risk factors in this category have an RII higher than 60, which means that these risks can significantly threat the project time and cost objectives.

5.1.5 Construction Risks

Construction risks are perceived to be the risks encountered or expected during the construction phase of the project. This category ranked fifth amongst the seven identified with an (RII = 62.72). The category contained the most number of risk factors i.e. ten. Construction delays (RII = 73.62) ranked the highest among this category with an overall ranking of six, according to its importance. Defective work & quality issues (RII = 71.88), insufficient technology (RII = 69.86), unexpected site conditions (dewatering/rock) (RII = 64.35), material shortage (RII = 63.77), scope of work not clear (RII = 61.45) were the significant risk factors in this category. Labor productivity (RII = 57.68), unexpected weather (rain/windstorm) (RII = 55.65), work interruptions or lack of space (RII = 55.07), over inspection or audits (RII = 53.33) were the somewhat important risk factors within this category. Construction process is inherently prone to risks, therefore the results also depict that six out ten risk factors are significant to very important having an RII greater than 60.

5.1.6 Contractual Risks

Contracts are legal bindings between two or more parties within a project. Contract management is an important aspect of bridge construction projects. This risk factor category ranked at number six out of seven (RII = 59.42), consisted of four risk factors, only one of these factors ranked in the top fifteen risk factors. Unrealistic schedules and cost-estimates (RII = 66.67). The other risk factors were change in project scope and change orders (RII = 61.74), disputes and claims (RII = 56.81), contractual anomalies (RII = 52.46). The overall RII is less than 60 depicts that these risks are less significant as compared to the aforementioned category, but their importance cannot be denied, specifically of the two risk factors with RII greater than 60 i.e. unrealistic schedules and cost-estimates and, change in project scope and change orders.

5.1.7 Health & Safety Risks

These risks can also be termed as physical risks. Occupational health and safety has been one of the intrinsic areas of research and development globally, not in Pakistan. Therefore these risks are ignored by the professionals, while addressing project cost and time. It ranked as the least important risk category (RII = 53.82). A total of three risk factors were identified in this category. Fatality (RII = 55.36), equipment and property damage (RII = 54.20) and accidents (RII = 51.88). These risk factors ranked at 31, 33 and 36 respectively, in order of importance. It is argued that all these risk factors have an RII less than 60, depicting that they can less significantly affect the project cost and time of project. The health & safety risks being rated so low could either mean that there is a lack of awareness of importance of occupation health & safety amongst the participants and lack of regulatory framework, which allows professionals not to be concerned about the physical hazards during the project.

5.2 COMPARISON WITH PREVIOUS RESEARCH

A comparison between the risk factors evaluated in this study and by (Ahmed et al., 2009) is carried out to verify the consistency of critical risk factors. This study has been specifically targeted to address risks affecting time and cost of bridge construction projects, whereas the other research accounted for the ranking of critical risk factors in the construction industry of Pakistan. The comparison is shown in Table 5.6 where top fifteen risk factors of each study are compared.

The top fifteen risks of both the studies are compared to verify whether the risks identified in this study were as important as previously. Unavailability of funds ranked first in this study and second by (Ahmed et al., 2009). Financial failure of contractor ranked second in this research and sixth in the other study. Poor site management and supervision ranked third in this study and twelfth in the other. Inadequate project planning ranked fourth and ninth. Defective work / quality issue ranked 14th by (Ahmed et al., 2009) and eighth in this study. Unrealistic cost-estimates ranked 15th in this research and surprisingly third in the other. It is pertinent to mention here, that risk factors in both the study had somewhat different names, and comparison was based on the similar risk factors. Although the ranking of factors was slightly different in both the studies, but eight out of top fifteen factors were similar in both the studies. The research carried out by (Ahmed et al., 2009) has resulted in a manner that none of the external risk (i.e. unavailability of land, delay in approvals from regulatory bodies, political instability, unstable government policies) are in the top fifteen risk factors, however they ranked at number 7 and 11 respectively in this study with an importance index greater than 60 i.e. very important risk factors.

Table 5.6: Comparison of results with previous research (Ahmed et al., 2009)

Risk Factor	Relative Importance Index	Risk Rank	Risk Factors, Previous research (Ahmed et al., 2009)	Risk Value	Risk Rank
Unavailability of funds	85.80	1	Differing site conditions	16.93	1
Financial failure of contractor	76.52	2	Inadequacy of project financing	16.36	2
Poor site management & supervision	74.20	3	Poor cost estimation (underestimation)	16.13	3
Inadequate site investigation	73.91	4	Inadequate/Inappropriate specification	15.72	4
Inadequate project planning	73.91	4	Incorrect/Inadequate site information	15.44	5
Construction delays	73.62	6	Internal cash flow issues	15.35	6
Unavailability of land ROW not clear	72.17	7	Construction change order/ directives	15.32	7
Defective work/ Quality issue	71.88	8	Lack of qualified craftsmen	14.61	8
Financial delays	71.01	9	Inadequate project planning	14.36	9
Insufficient technology	69.86	10	One-side contracts, Inappropriate contract terms	14.17	10
Insufficient engineers & specialists	69.28	11	Over-Inspection / audits	14.16	11
Delay in approvals from regulatory bodies	69.28	11	Poor site management & supervision	14.08	12
Political instability	69.28	11	Disputes / Claims and related issues	14.06	13
Unstable government policies	66.96	14	Defective work / quality issues	13.80	14
Unrealistic cost estimates & schedules	66.67	15	Labor productivity issues	13.78	15

5.3 CASE STUDY OF A BRIDGE PROJECT

The case study of bridge over river ling was undertaken as part of this thesis. The study of the project included interaction with professionals executing the project, studying and evaluating the project documents and, analysis of critical risk factors affecting cost and time objectives of the project. This systematic process was carried out with full cooperation of the project participants. The study period of the project was from (October 2010 to March 2011). The author of this thesis stayed full time on the site to ensure maximum learning and later to disseminate lessons learned.

The bridge project was scheduled to start on 26-October-2009 and finish on 15-July-2011. The base cost estimate for project completion was Pakistani Rupees 129,221,836. For the purpose of this research, a baseline schedule was first developed, activity-wise cost was assigned. A risk register was than created and simultaneously risks were assigned to activities. The MC simulations were then performed on this schedule to evaluate the impact of risk factors.

This exercise resulted in the form of following outcomes:

- Probability of deterministic values (i.e. baseline cost & time)
- Time & cost with 80% confidence.
- Time & cost with 100% confidence.
- Comparison with actual time & cost.

The stochastic model suggests that there is a 4% probability that the project would finish within the budgeted cost. A very low probability of less than 1% to finish project within the baseline time, gives an alarm to the management of that organization.

While comparing the results of the simulation with the actual dates and cost of activities, the suitability of the analysis was observed. The prediction of risk and their impacts actually performed in an appreciable manner, generating results close to real time situation.

It is evident to mention here that duration estimates of activities varied with a considerable amount from those forecasted. The actual values of cost and finish dates were in between the forecasted values with 80% and 100% confidence respectively.

During the observatory period, only four activities i.e. piles, pile caps, pier shafts and transoms of the project were completed. Thus the actual comparison of time and cost with that of forecasted results can be drawn of these activities only. Tables 4.8-4.12 gave an explicit idea that project is already behind time and cost, due to occurrence of critical risks and non-existence of a risk management framework has allowed these risk to impact the cost and time objective of the project.

From the results it can easily be depicted that the risk estimation carried out for this study performed very well, the risks identified were actually effective and faced in the real time construction of the project. Nonetheless, due to non-existent of risk management framework none of the risks were managed or treated effectively.

Chapter 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

Amid the failure of various bridges globally and in Pakistan, this research is targeted to ensure awareness of project stakeholders about the threats affecting the performance in the construction process of a bridge project, they are likely to face. This research is unique in a way that a project case study is explained to develop a better understanding using the realistic data compared with computational simulation of risks. The potential risks related to bridge construction projects were identified and analyzed. From the results of the case study it showed that the forecasted results were approximately accurate and similar to those actually executed in terms of project cost and time.

The key findings of this research were the exploration of critical risk factors affecting the time and cost objectives of a bridge project. These risk factors were divided into categories and then analyzed. Factor analysis was carried out to rank these risks according to their importance. This will help the project stakeholders while initiating new projects in identifying the important threats they are likely to face as the project progresses.

Risk analysis procedure may look as one of the most difficult and tiresome process of the risk management process, but it is on the contrary. It involves exploration of data, utilizing it and use of knowledge from experts. It is argued that the project stakeholders within Pakistan must start this exercise as a part of their management technique. The forecasting actually helps in decision making and can identify areas of concern for the management early on in the project.

The importance of project risk management cannot be denied. Therefore the results of this thesis also urge the professionals to start awareness regarding this intrinsic area. A manager would not be happy to see his project behind cost and schedule the remedy lies in a comprehensive risk management framework.

The key risk factors can be benchmarked, as this is the first of its kind study in Pakistan and can later be used to develop response strategies in future research.

6.2 CONCLUSIONS

6.2.1 Importance of Risks

The research has identified critical risk factors according to their importance and prioritized them in order of impact to project cost and time objectives. The risk rating is a useful technique to measure the importance of risk factor. The relative importance index (RII) has resulted in identification of one extraordinary, twenty four major and twelve moderate risk factors according to the risk rating devised within this research.

Overall ranking of risks basing on their RII is: (1) unavailability of funds also rated as the extraordinary risk factor; (2) financial failure of contractor; (3) poor site management and supervision; (4) inadequate site investigation; (4) inadequate project planning; (6) construction delays; (7) unavailability of land / right of way not clear; (8) defective work / quality issue; (9) financial delays; (10) Insufficient technology; (11) insufficient engineers and specialists; (11) delay in approvals from regulatory bodies; (11) political instability; (14) unstable government policies; (15) unrealistic schedules and cost estimates; (16) economic disaster; (17) unexpected site conditions (dewatering / rock); (18) design changes; (8) material shortage; (20) hike in material prices; (21) subcontractor failure; (22) change in project scope / change orders; (23) lack of coordination; (23) scope of work not clear; (25) design not complete. Factors ranked from 2 to 25 were rated as major according to risk rating; (26) Inflation; (27) labor productivity; (28) disputes / claims; (29) unexpected weather (rain / windstorms); (29) third party delays; (31) fatality; (32) work interruptions / lack of space; (33) equipment and property damage; (34) over inspections and audits; (35) contractual anomalies; (36) accidents and (37) strikes and thefts.

Risk Factors from 26 to 37 were rated as moderate in affecting the bridge projects time and cost objectives. The relative importance index measure of these 37 identified risk factors has formed the basis for future research on response of these risk factors as well as to the professionals working in the industry as an authentic evidence for use, while identifying the risks for their projects.

6.2.2 Risk Analysis Guidelines

Through this research it is intended to present the guidelines necessary for a successful risk analysis of bridge projects. A stepwise guideline is provided below, which shall help the professionals working on bridge projects. Guidelines are prepared by keeping in view the evidence of (Schuyler, 2001) and (Loosemore et al., 2006).

- **Develop the context**

Developing the context, relates to defining the scope of project, systematically conduct stakeholder analysis, developing the project method statement. This would serve as the boundary of risk analysis. Variables and factors contributing to project risk could then easily be identified in the next step.

- **Identify risks**

Risk identification process explained in detail in chapter number two of this thesis consists of various tools and techniques these may include checklists, brainstorming, historical data, and idea elicitation techniques. After the context within which risk are to be analyzed is defined, identifying risk is an easy process. Using the above mentioned or other techniques, risks that can impact the project performance in terms of time and cost are listed down and will now be evaluated or quantified in the next step.

- **Quantify risks**

The quantification of risk is a foremost important process and in fact the one which requires extensive experience, judgment and skills. In the risk quantification process likelihood i.e. probability of a risk is to be assessed. After the probability, its impact needs to be formulated; impact can be in terms of cost and time. It is a quantitative characteristic but can also be assigned qualitatively and later converted into quantitative. The relation of risk with the other is an important part, which has been addressed in this study. The correlation of a risk with another can either be positive or negative, which means that the impact of a risk increases with an increase in impact of the other risk reflected by a positive correlation and a negative correlation would mean reducing the impact of one risk can increase the impact of other and viz-a-viz. The Pearson's Product Moment Correlations have been carried out for this research. Risk distribution can either be uniform, triangular or beta pert; they have been explained in the literature review chapter. Deciding the type of distribution a risk would follow is an important part of risk quantification and requires historical data. The last step in risk quantification is to decide which activity these risks can affect, whether the risk has an effect on activity(s) cost and time or both.

- **Formulate the project cost-loaded schedule**

The project baseline schedule is to be formulated on the base of project method statement and contract document. If the context of the project is developed completely, formulating the project schedule will be an easy task. Each activity of the project schedule is to be assigned a cost. Project cost estimation should be carried out in a manner that it is developed activity wise, so that assigning cost to scheduled activities does not become a cumbersome task. This schedule which has cost assigned to it, should be saved as a baseline. In order to evaluate the impact of risks identified and quantified earlier the measurement of cost and time to the computational results will be done with the help of a baseline. Without saving a baseline, it would be impossible to measure the effect of the risk factors.

- **Load the schedule with risks**

After completion of a well formulated cost-loaded schedule, next task is to assign it with the risks identified and quantified earlier. The risks identified and quantified are to be documented in the form of a risk register. This risk register incorporates all the details of risks applicable to the project schedule. A complete cost-loaded schedule is now assigned the relevant identified risks, with help of a risk register.

- **Run MC simulations**

Monte Carlo (MC) simulations as discussed in detail, in chapter two and four is the random number probabilistic method. The schedule developed and loaded with risk should be subjected to MC simulations in order to evaluate the risk impact. The MC simulations can be performed using different software's. For the purpose of this research, Pertmaster V8 was used.

- **Understanding the output.**

The outputs generated by these simulations are easy to understand. The problem arises when there is a misconception of risk analysis. Outputs generated are the confidence of the deterministic values. These are the baseline cost and time; the confidence is the probability of meeting these objectives. Next are the P80 and P100 values, which are 80% and 100% probability respectively, indicating the values of cost and time with 80% and 100% confidence. From the outputs, it is easy to understand how much can an activity be delayed from its original time and how much cost can overrun. These impacts are useful for the next step in the risk management process i.e. risk response planning, which is not a part of this research work.

6.3 RECOMMENDATIONS

- Financial and economic factors are the most important risks facing the construction industry followed by site management risks. A systematic study may be carried out to mitigate the adverse impacts of these risks, individually and collectively, on the project objectives.
- This research has identified numerous risk factors for the bridge projects. However, similar studies can be performed on other civil engineering areas (e.g. building projects, infrastructure e-t-c).
- The case study project selected is built using the self-performed project delivery method where an owner plays the major role during the construction phase, utilizing his own workforce. Similar studies can be performed on

different projects, with a different project delivery method. This can further foster the concepts of project stakeholders about risk analysis.

- MC simulation can also be used to analyze threats to other objectives such as quality which is a technical risk; further research may target to study the affect of quality risks on a project using MC simulations.
- An attempt to develop a risk analysis model for bridge construction projects can be a next step using the data from this research and if developed can be useful for various settings, not just Pakistan.

REFERENCES

Ahmed, S. M., Lodi. S. H., and Farooqui, R. U. (2009). "Development of a Strategic Model for Improvement of Construction Project Management Education, Research, and Practice in Pakistan". The National Academics, Policy and Global Affairs, NW, Washington, DC, 278-339.

Akintoye, S. A. and Macleod, M.J. (1997) "Risk Analysis and Management in Construction". *International Journal of Project Management*, 15(1), 31-38.

American National Standard. (2004). "*Project management body of knowledge*." ANSI/PMI 99-001-2004, USA.

Carmines E. G. and Zeller R. A. (1979). "Reliability and validity assessment." Newbury Park: Sage Publication, UK.

Chan D. W. M. and Kumaraswamy M. M. (1997). "A comparative study of causes of time overruns in Hong Kong construction projects. *International Journal of Project Management* 15(1), 55-63

Chaudhry, S. M., and Kamal, S. (2008). *"Introduction to statistical theory."* Ilmi Kitab Khana, Urdu Bazar, Lahore, Pakistan.

Dept. of the Navy. (1958). "PERT, program evaluation research task." Phase 1 Summary rep., special Projects Office, Bureau of Ordnance, Washington, D.C.

Dikemen, I., Birgonul, M.T., and Arikan, A.E. (2004). "A critical review of risk management support tools." Proc., ARCOM 2004, Association of Researchers in Construction Management, Heriot Watt University, U.K., 1145-1154.

Dillon, R. L., and Paté-Cornell, M.E. (2001). "APRAM: an advanced programmatic risk analysis method." *International Journal of Technology, Policy & Management*, 1(1), 47-55.

Farooqui, R.U., Lodi, S. H., and Saleem, F. (2007). "Risk Management and Trends among Construction Contractors in Pakistan". Fourth International Conference on Construction Industry in the 21st Century: Accelerating

Innovation in Engineering, Management and Technology (CITC IV 2007), Gold Coast, Australia, July 11-13.

Federal Bureau of Statistics (FBS). (2010). "*Pakistan Statistical Year Book-2010."* Statistics Division, Government of Pakistan.

Field A. (2000). "Discovering statistics using SPSS for windows: advance techniques for the beginner." Great Britain: Sage Publication.

Flanagan, R., and Norman G. (1993). "Risk management and construction, Blackwell Scientific Publications, Osney Mead, Oxford, London.

Flanagan, R., and Norman, G. (1999). "*Risk management and construction*." Blackwell Science Ltd, Oxford, UK.

Geourge D. and Mallery P. (1999). "SPSS for windows step by step : a simple guide and reference." USA: Allyn and Bacon.

Ghosh, S. and Jintanapakanont, J. (2004). *International Journal of Project Management*, 22(1), 633-643.

Imbeah, W. and Guikema, S. (2009). "Managing Construction Projects Using the Advanced Programmatic Risk Analysis and Management Model." *Journal of Construct Engineering & Management* 135(8), 772-781.

Iqbal, K. (2011). "Risk Management in Construction Industry of Pakistan" MSc. Thesis in Construction Engineering & Management, National Universisty of Sciences & Technology, Pakistan.

Lian, Y. and Yen, C. B. (2003). "Comparison of Risk Calculation Method for a Culvert." *Journal of Hydraulic Engineering,* 129(2), 140-152.

Loosemore, M., Raftery, J., Reilly, C., and Higgon, D. (2006). "Risk management in projects." Taylor & Francis, London, UK.

Loosemore, M., Raftery, J., Reilly, C., and Higgon, D. (2006). "*Risk management in projects*." Taylor & Francis, London, UK.

Masood, R., and Choudhry, R, M. (2010). "Identification of risks factors for construction contracting firms – encompassing mitigation stance." Paper for second international conference on construction in developing countries, August 3-5, 2010, Cairo, Egypt.

Ministry of Finance. (2010). *"Fiscal policy statement 2009- 10."* Debt Policy Coordination Office, Government of Pakistan.

Nasir, D., McCabe, B., and Hartono, L. (2003) "Evaluating Risk in Construction-Schedule Model (ERIC-S): Construction Schedule Risk Model." *Journal of Construction Engineering & Management*, 129(5), 518-527.

Nunnally J. C. (1978). "Psychometric theory." 2nd ed. USA: McGraw-Hill.

Ökmen, Ö., and Öztas, A. (2008). "Construction Project Network Evaluation with Correlated Schedule Risk Analysis Model" *Journal of Construction Engineering & Management*, 134(1): 49-63.

Schuyler, J. (2001). "Risk and Decision Analysis in Projects." Project Management Institute, Pennsylvania, USA.

Shash AA. (1993). "Factors consider in tendering decisions by top UK contractors." Construct Management & Economics, 11(2), 111-8.

Standards Association of Australia. (1999). "*Risk management."* AS/NZS 4360, Australia.

State Bank of Pakistan. (2010). "*Economic Survey 2009-10*." Islamabad, Pakistan.

State Bank of Pakistan. (2011). "*Monetary policy statement january 2011*." Islamabad, Pakistan.

Transparency International Pakistan. (2010). *"National corruption perception survey 2010."* 5 C, 2nd Floor, Khy-e-Ittehad, Phase VII, DHA, Karachi, Pakistan.

World Bank. (2010). "*Expanding housing finance to the Underserved in South Asia*" Washington, DC.

World Bank. (2011). *"Doing Business 2011."* Washington, DC.

Appendix I

QUESTIONNAIRE

General Information (Will Not be Published)	
Name of Respondent	
Experience in Construction Industry (Years)	
Organization	
Designation	

IMPORTANCE OF RISKS

S.NO	MAJOR RISKS	IMPORTANCE OF RISKS 1 = Insignificant, 2 = Minor, 3 = Moderate 4 = Major, 5 = Extraordinary				
		1	2	3	4	5
	Financial & Economic Risks					
1	Economic disaster					
2	Financial delays					
3	Financial failure of contractor					
4	Hike in material prices					
5	Inflation					
6	Unavailability of funds					
	Contractual Risks					
7	Change in project scope / Change Orders / Directives					
8	Contractual anomalies					
9	Disputes / Claims					
10	Unrealistic schedules and cost estimates					
	Design Risks					
11	Design changes					
12	Design not complete					
13	Inadequate site investigation					
	Health and Safety Risks					
14	Accidents					
15	Equipment and Property Damage					
16	Fatality					
	Management Risks					
17	Inadequate project planning					
18	Insufficient engineers & specialists					

19	Lack of coordination					
20	Poor site management and supervision					
21	Strikes & Theft					
S.NO	MAJOR RISKS	IMPORTANCE OF RISKS 1 = Insignificant, 2 = Minor, 3 = Moderate 4 = Major, 5 = Extraordinary				
		1	2	3	4	5
22	Subcontractor failure					
	Construction Risks					
23	Construction delays					
29	Scope of work not clear					
30	Unexpected site conditions					
31	Unexpected weather (rain/windstorm)					
32	Work interruptions / Lack of space					
	External Risks					
33	Delay in approvals from regulatory bodies					
34	Political instability					
35	Third party delays					
36	Unstable government policies					
37	Unavailability of land / ROW not clear					